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An Investigation into the use and Effectiveness of Post-Exercise Recovery Protocols for Team Sport

Fiona Alyce Crowther (formerly Pringle)

BSpExSc(Hons)

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College of Healthcare Sciences

James Cook University

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The proposed research studies received human research ethics approval from JCU Human Research Ethics Committee, Approvals H5248, H5415 and H5969.

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Fiona Crowther Date

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Nature of Assistance	Contribution	Names, titles and affiliations of co-contributors
Intellectual Support	Proposal writing	Associate Professor Rebecca Sealey (JCU)
		Dr. Melissa Crowe (JCU)
		Professor Andrew Edwards (University of St Mark and St John)
	Data analysis	Associate Professor Rebecca Sealey (JCU)
		Dr. Melissa Crowe (JCU)
		Dr. Shona Halson (Australian Institute of Sport)
		Professor Andrew Edwards (University of St Mark and St John)
	Data input	Benjamin Crowther
		Keegan Chatburn (JCU)
		Madeleine Pasqualie (JCU)
	Statistical analyses	Associate Professor Rebecca Sealey (JCU)
		Dr. Melissa Crowe (JCU)
		Dr. Theophilus Emeto (JCU)
		Gary Williams (JCU)
		Associate Professor Kerrianne Watts (JCU)
	Graphic and figure design	Professor Andrew Edwards (University of St Mark and St John)
		Associate Professor Rebecca Sealey (JCU)
		Dr. Melissa Crowe (JCU)
		Dr. Shona Halson (Australian Institute of Sport)
		Professor Andrew Edwards (University of St Mark and St John)
	Editorial assistance	Benjamin Crowther
		Associate Professor Rebecca Sealey (JCU)
		Dr. Melissa Crowe (JCU)

		Dr. Shona Halson (Australian Institute of Sport) Professor Andrew Edwards (University of St Mark and St John)
Financial support	Data collection funds	Associate Professor Rebecca Sealey (JCU) Dr. Melissa Crowe (JCU)
Data collection	Research assistants (predominantly JCU students undertaking supervised placement hours)	Jessica Champion (JCU) Luke Adams (JCU) Rodrigo Brito (JCU) Naomi Fines (JCU) Kerri Henderson (JCU) Jordan Young (JCU) Jennifer Simmons (JCU) Rachel Warcon (JCU) Radostina Chalakova (JCU) Nakita Hollingsworth (JCU) Hailee Frost (JCU) Lance Imo (JCU) Mary Malan (JCU) Sonja Martin (JCU) Leesa Pearce (JCU) Kaitlin Talbot (JCU) Tacita Thorogood (JCU) Stacie Quirke (JCU) Madeline Hill (JCU) Katelyn Lawlor (JCU) Ho Yat Kam (JCU) Anthony Cutts (JCU) Keegan Chatburn (JCU) Madeleine Pasqualie (JCU) Benjamin Crowther Melissa Pringle (JCU) Jenny Skinner Teneale McGuckin (JCU)

	Associate Professor Rebecca Sealey (JCU)
	Alex Bennett
	Bethwyn McIldowie (JCU)
	Emma Crowther
	Zainab Djawas-Armstrong (JCU)
	Harrison Sloan (JCU)
Assistant research conductor	Catherine DeHollander (JCU)

Abstract

A variety of post-exercise recovery strategies are used by team sport athletes. However, little research has investigated the use of recovery strategies by team sport athletes across a range of competition levels. Furthermore, equivocal evidence exists to support the use of one recovery strategy over another. The aim of this thesis was therefore to investigate recovery usage by team sport athletes across a range of competition levels in various sports, and the effects of differing recovery strategies after single and multiple bouts of simulated team sport match-play exercise.

A systematic review of the literature revealed CWI, CWT and ACT produced mostly equivocal effects in comparison to CONT for performance and perceptual recovery. Cold water immersion and CWT also improved performance and perceptual recovery in a number of instances, CWI also decreased performance in a small number of instances. No differences were indicated between ACT and CONT for performance recovery and mostly for perceptual recovery, with a small number of decreases after ACT in comparison to CONT for perceptual recovery. Current evidence was therefore not conclusive on the effectiveness of these recovery strategies.

Three original studies are subsequently presented in this thesis that aim to address the current unclear evidence on recovery strategies. The aim of the first study (Chapter 3) was to identify via survey which recovery strategies are currently used by Australian male and female team sport athletes of varying competition levels. Three hundred and thirty-one athletes were surveyed across fourteen team sports and five levels of competition; 57% of whom reported utilising one or more recovery strategies. All international athletes reported using massage for recovery. Athletes of all other

competition levels utilised stretching (STR) the most (98% national, 79% state, 87% regional and 77% local athletes). Water immersion strategies were most often used by national and international athletes. Stretching was self-rated the most effective recovery strategy (4.4/5; where 5 = very effective) with active, land-based (ALB) considered the least effective by its users (3.6/5). Laziness and time constraints were the main self-reported reasons provided by those who did not undertake a specific recovery strategy. Water immersion strategies were considered effective or ineffective largely due to psychological reasons. In contrast STR and ALB were considered to be effective or ineffective mainly due to physical reasons. Results from Chapter 3 indicate that the perceptions of athletes on recovery strategy effectiveness did not always align with scientific evidence. The availability of particular recovery strategies may also affect recovery strategy selection. It is recommended that athletes and coaching staff are provided with up-to-date information on the effects of different recovery strategies to ensure informed decisions are made regarding recovery strategy selection.

The aim of the second study (Chapter 4), a randomised controlled trial (RCT; $N = 34$), was to compare the effectiveness of CWI, CWT, ACT, a combination of cold water immersion and active recovery (COMB) and a control (CONT) condition after a single bout of simulated team-game circuit exercise (55 min). Performance and perceptual recovery indices were assessed over a 48 hr time period. Results suggest that CWI and COMB produced detrimental jump power performance at 1 hr compared to CONT and ACT, and thus should not be selected for short term recovery. It is likely that 1 hr was not sufficient time for muscles to rewarm after CWI and COMB resulting in decreased jump performance at this time. Findings also suggest CWT should be elected for short-term perceptual recovery after a team sport game. The heat component of CWT may have contributed to feelings of relaxation and accordingly enhanced perceptions of recovery. No between recovery differences were found at 24 and 48 hr post the simulated team-game circuit exercise.

The aim of the third study (Chapter 5; *N* = 14) was to examine the use of CWI, CWT, ACT, COMB and CONT recovery across repeated small-sided games simulating acute tournament match-play (three 15 min efforts, 3 hr apart, with recovery after bouts 1 and 2) upon performance, perceptual and physiological indices of recovery over an 8 hr time period. Results indicated that CWT was superior to ACT for performance, and COMB was superior to ACT and CONT for perceptual recovery during the simulated tournament day. The ACT recovery was detrimental to performance and perceptual recovery and thus a similar ACT recovery protocol should not be elected for use in a team sport multiple-game tournament day. The mechanisms most likely associated with the beneficial CWT findings compared to ACT include a combination of the negative effects of ACT such as no rest and increased energy consumption and the positive effects of CWT such as the alternation between vasoconstriction and vasodilation. During a COMB recovery the actions of hydrostatic pressure and leg movement may assist with blood flow and enhanced perceptions of recovery. The ACT recovery is most likely detrimental during a tournament day due to the extra metres covered, adding to the experienced soreness and fatigue.

The results of the RCTs question the high anecdotal use of CWI by national and international athletes as reported in the survey, with CWI found to have no positive effect upon performance or perception after a single bout of a simulated team sport or during a simulated tournament day.

In conclusion, the current research has highlighted the need for athlete and coach education on the effects of recovery strategies, noting the limitations associated with the inconclusive nature of evidence regarding the use of specific recovery strategies. Contrast water therapy is recommended to be used for short term perceptual recovery after a single team sport event. A COMB recovery should be elected for superior perceptual recovery over a team sport tournament day. The research presented in this thesis has significantly contributed to post-exercise recovery research by providing an overview of recovery strategy use by Australian-based team sport athletes and by providing evidence-based recommendations from trials that compare the effectiveness of various recovery strategies used by team sport athletes. These findings provide athletes and coaches with up-to-date information to assist with informed decision making about their recovery choices in particular sports and contexts. Recommendations for future research have also been identified, including investigation into whether performance or perceptual recovery is more important and whether individualised recovery is required for optimum team performance.

Research Outputs

Crowther, F., Sealey, R., Crowe, M., Edwards, A., & Halson, S. (2017). Team sport athletes' perceptions and use of recovery strategies: a mixed-methods survey study. *BMC Sports Science, Medicine and Rehabilitation, 9*(6). doi:10.1186/s13102-017-0071-3

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Peer-reviewed Conferences

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Glossary Terms of Key Recovery Strategies

Term	Definition
Active recovery	A recovery that involves low-intensity movement of the body, e.g. walking, jogging.
Cold water immersion	Immersion in cold water.
Combined recovery	A combination of cold water immersion and active recovery.
Contrast water therapy	Alternation between immersion in cold water and hot water.
Control recovery	Passive recovery, e.g. seated rest.

Abbreviations and Units of Measurement

Abbreviation	Full term
ACT	Active recovery
ALB	Active, land-based recovery
ASIS	Anterior superior iliac spine
ATP	Adenosine triphosphate
AWB	Active, water-based recovery
bpm	Beats per minute
CI	Confidence interval
CMJ	Countermovement jump
COMB	Combined recovery
CONT	Control recovery
CWI	Cold water immersion
CWT	Contrast water therapy
DALDA	Daily analysis of life demands for athletes
DOMS	Delayed onset muscle soreness
EMG	Electromyography
hr	Hour
HWI	Hot water immersion
IVS	Internal validity scale
kg	Kilogram
kJ	Kilojoule
m	Metre
max	Maximum

MDC	Minimum detectable change
min	Minute
mmol/L	Millimole per litre
Predicted $\dot{V}O_2max$	Predicted maximal oxygen consumption calculated from the multi-stage fitness test (Section 4.3) or the yo-yo intermittent recovery test (Section 5.3).
r	Correlation value
RCT	Randomised controlled trial
RPE	Rating of perceived exertion
RPErec	Rating of perceived exertion recovery
SD	Standard deviation
sec	Second
SJ	Squat jump
STR	Stretching
TQR	Total quality recovery
W	Watts

Chapter 1

Introduction

1.1 Background

A structured, post-exercise recovery routine may be undertaken by athletes for a number of reasons, including reducing the risk of injury and fatigue, and to increase the ability to perform at one's best in their next game/training session (Barnett, 2006; Hing, White, Bouaaphone, & Lee, 2008). Without adequate recovery, delayed onset muscle soreness (DOMS) may occur, which could induce a number of symptoms such as muscle tenderness, debilitating pain and a reduction in joint range of motion (Cheung, Hume, & Maxwell, 2003), all of which may contribute to subsequent, decreased performance. Although recovery strategies have played an integral role in post-exercise routines for many years particularly following competitive sport, the effectiveness of different recovery strategies is difficult to assess and define. Various physical, perceptual and physiological variables have thus far been used as indicators to test the extent of recovery strategy effectiveness, such as a treadmill run to exhaustion, rating of perceived exertion recovery, blood lactate, (Coffey, Leveritt, & Gill, 2004) countermovement jump (CMJ), repeated sprint ability, overall fatigue, leg soreness, (Delextrat, Calleja-González, Hippocrate, & Clarke, 2012), 20 m sprint, vertical jump and perceived soreness (Getto & Golden, 2013). Of these variables, no clear empirical evidence exists as to which variables are considered the most important indicators of recovery for athletes and coaches across a range of sports and competition levels. This is likely to vary depending on the type of activity undertaken (type of sport, duration, intensity etc), the context of the activity (repeated, single) and individual attributional style.

Although it is generally accepted that athletes undertake different types of post-exercise recovery strategies, both in response to the same task and also across different activities, to the authors' knowledge there is currently no comparative research available to describe which recovery strategies are used by Australian athletes across a range of team sports and competition levels. It is also unclear why athletes undertake recovery strategies and believe they are effective or ineffective.

For many years, recovery strategies have been recommended in sports trainer course manuals (e.g. Sports Medicine Australia, 2007) and have been encouraged by mainstream media (Christian, n.d.) to be part of post-exercise routines. A variety of recovery strategies are utilised by athletes, some of which include: cold water immersion (CWI), contrast water therapy (CWT), active recovery (ACT), stretching (STR), massage, compression garments, electrostimulation, cryotherapy, pool recovery, sleep, nutrition, fluid replacement, ice application, heat application, gel application, progressive muscle relaxation, prayer, music, reflexology, acupuncture, supplements and medications (Halson, 2013; Simjanovic, Hooper, Leveritt, Kellmann, & Ryne, 2009; Venter, Potgieter, & Barnard, 2010). During the 1960's scientific investigation into recovery strategies began with research published on the effectiveness of post-exercise STR (Devries, 1961) and the effects of ACT on lactate removal and oxygen debt (Gisolfi, Robinson, & Turrell, 1966). These studies reported early evidence of the effectiveness of these recovery strategies which have continued to be investigated in recent times (Bielik, 2010; Monedero & Donne, 2000; Watts, Daggett, Gallagher, & Wilkins, 2000; Wiltshire et al., 2010). Massage, CWI, CWT and a combination of active and cold water immersion (COMB) post-exercise recovery research began appearing in the 1990s (Cafarelli, Sim, Carolan, & Liebesman, 1990; Eston & Peters, 1999; Hudson, Loy, Vincent, & Yaspelkis III, 1999; Kuligowski, Lephart, Giannantonio, & Blanc, 1998; Martin, Zoeller, Robertson, & Lephart, 1998); and continues today (Coffey et al., 2004; Crampton, Egaña, Donne, & Warmington, 2014; Farr, Nottle, Nosaka, & Sacco, 2002; Getto & Golden, 2013; Gill, Beaven, & Cook, 2006; Juliff et al., 2014; Versey, Halson, & Dawson, 2011; White, Rhind, & Wells, 2014) with contrasting effectiveness noted. The use of compression garments (Duffield, et al., 2008; Jakeman, Byrne, & Eston, 2010; Kraemer et al., 2010), electrostimulation (Lattier, Millet, Martin, Martin, & 2004; Malone, Coughlan, Crowe, Gissane, & Caulfied, 2012; Vanderthommen, Makrof, & Demoulin, 2010) and cryotherapy (Costello, Algar, & Donnelly, 2012; Hausswirth et al., 2011) as post-exercise recovery strategies have also been investigated in recent years with contrasting results, as athletes and support staff search for novel, alternative, superior recovery strategies that may provide a competitive edge.

In addition to ongoing experimental research on the various recovery strategies, numerous reviews have been published in an effort to compare, contrast and synthesise the available evidence (Barnett, 2006; Howatson & van Someren, 2008; Kovacs & Baker, 2014; Nédélec et al., 2013; Torres, Ribeiro, Duarte, & Cabri, 2012). These reviews show conflicting findings that are often dependant on the recovery strategy protocol, the type and intensity of the fatiguing stimulus and the recovery outcome variables used in the experiment.

Reviews focussed on stretching and massage have resulted in varying conclusions. While Barnett (2006) and Nédélec and colleagues (2013) reported no effect upon post-recovery performance and perceptual responses; other reviews have deduced that both stretching and massage improved perceptions of muscle soreness (Howatson and van Someren, 2008; Torres at el., 2012). A number of systematic reviews have investigated massage and found it to produce inconclusive results, thus more research has been recommended to confirm whether it is an effective recovery strategy or not (Best, Hunter, Wilcox, & Haq, 2008; Ernst, 1998; Hemmings, 2001). Kovacs and Baker (2014) found compression garments to assist in tennis performance, while in contrast Nédélec and colleagues (2013) identified no benefit for soccer recovery. All reviews on electromyostimulation (Barnett, 2006; Kovacs & Baker, 2014; Nédélec et al., 2013; Howatson and van Someren, 2008) and non-steroidal anti-inflammatory drugs (Barnett, 2006) concluded that no benefit to recovery was evident. Maintaining good hydration, diet and sleep patterns however, have all been shown to be of benefit to recovery (Kovacs & Baker, 2014; Nédélec et al., 2013).

Recovery strategies such as achieving quality sleep, good hydration and well-balanced food consumption may be considered by some athletes to be a normal daily process that follows competition and/or training, and not as a deliberate recovery strategy. Nevertheless, they are important aspects of post-exercise behavior that should not be neglected in the study of recovery. In contrast, dedicated post-exercise interventions such as water immersion recovery strategies and ACT are recovery choices undertaken with the specific purpose of recovery, and are strategies that can be undertaken as a team and hence will be investigated further in this thesis.

1.2 Physiological Response to Exercise

The body responds to intense exercise in a number of different ways. Firstly, adenosine triphosphate (ATP) synthesis and oxygen consumption are increased in order to support greater metabolic work (Powers & Howley, 2004). If exercise is prolonged and intense, there will also be an increase in heart rate to supply necessary oxygen to working muscles and elevated hydrogen ion concentration due to carbon dioxide and lactate formation, causing a decrease in blood pH (McArdle, Katch & Katch, 2010). Acidosis which is an increase in hydrogen concentration (decreased pH) is associated with sensations of pain and discomfort emanating from active muscles (McArdle, et al., 2010), causing a reduction in performance. As the body requires more ATP, an accumulation of inorganic phosphate from creatine phosphate and ATP breakdown may hinder the release of calcium from the sarcoplasmic reticulum and potentially the release of inorganic phosphate from myosin during the power stroke of the cross bridge cycle, causing decreased muscle activation (Marieb & Hoehn, 2013).

Athletes may also feel a reduction in the desire to continue exercise, which may be due to central fatigue. Central fatigue is a type of fatigue that is associated with alterations of the central nervous system (CNS) which may impact upon sensation of effort, mood and tolerance to discomfort and pain (Meeusen, Watson, Hasegawa, Roelands, & Piacentini, 2006). The exact cause of central fatigue is still highly debated (Meeusen et al., 2006; Edwards & Polman, 2012). Peripheral fatigue may also be experienced; which is fatigue occurring in the muscles (Edwards & Polman, 2012). This type of fatigue is caused by events that occur independently of the CNS, such as disturbances to excitation-contraction coupling, neuromuscular transmission and sarcolemma excitability (Meeusen et al., 2006). Meeusen and colleagues (2006) state that fatigue is a complex interaction between both peripheral and central factors that mutually influence each other.

The following processes must take place after fatiguing exercise for normal muscle function to be restored; oxygen in myoglobin must be restored, accumulated lactate needs to be reconverted to pyruvic acid, the replenishment of glycogen stores and the resynthesis of ATP and creatine phosphate stores (Marieb & Hohen, 2013). For the body to undertake these restorative process, excess oxygen must be taken in via a process called excess postexercise oxygen consumption (Marieb & Hohen, 2013; Martini, 2005). It is important that a post-exercise recovery is able to restore normal muscle function as discussed.

The following is a brief summary of major research findings and associated physiological and perceptual mechanisms for CWI, CWT, ACT and COMB recovery strategies. A detailed critical appraisal and discussion of the literature is presented in Chapter 2.

1.3 Cold Water Immersion

Cold water immersion elicits physiological changes within the body, caused by the effects of hydrostatic pressure and the cold temperature of the water. Hydrostatic pressure is the compressive force that acts upon the body when immersed (Wilcock, Cronin, & Hing, 2006) due to the weight of the water. The external hydrostatic pressure due to water causes the gases and liquids within the body to become compressed and to move to areas of lower pressure (Wilcock et al., 2006). This allows fluids from the intracellular spaces to move to the blood and facilitates venous return (Kaczmarek, Mucha, & Jarawka, 2013), increases cardiac output and reduces peripheral resistance (Wilcock et al., 2006).

Exercise can cause localised oedema due to tissue damage in working muscles. Oedema may result in the activation of pain receptors (Kaczmarek et al., 2013), thus eliciting post-exercise soreness or tenderness in the muscles stressed by exercise. It is plausible that hydrostatic pressure could reduce oedema via a pressure gradient-induced reduction in inflammatory cell influx into fatigued or damaged muscle (Wilcock et al., 2006). A reduction to oedema could therefore better sustain normal blood flow and may result in enhanced nutrient delivery for muscle recovery, while less swelling would also decrease limb pain, which in turn would enhance the perception of recovery (Wilcock et al., 2006) and potentially performance.

Exposure of the body to cold water when immersed redirects blood from the periphery to the core to maintain core body temperature via peripheral vasoconstriction (Wilcock et al., 2006). Peripheral vasoconstriction increases venous return, stroke volume, and cardiac output (White & Wells, 2013). Vasoconstriction also reduces oedema (Wilcock et al., 2006). It is assumed that the peripheral vasoconstriction decreases fluid diffusion and therefore combines with the effect of hydrostatic pressure to further reduce muscle inflammation and reduce pain perception.

If the body is immersed in water that is cold enough and for a sufficient time to induce tissue cooling, reduced pain (analgesia) may also occur as a result of a reduction in the neurotransmitter rate due to a decrease in the production of acetylcholine (Kaczmarek et al., 2013). The analgesic effect may allow for mobility with reduced pain (White & Wells, 2013).

While CWI therefore could enhance performance recovery via a combination of physiological changes within the body, it should be noted that an increase in metabolism (Wilcock et al., 2006) and oxygen consumption (Ishan, Watson, & Abbiss, 2016) may occur as a protective effect to maintain core temperature if shivering commences. This would result in greater energy expenditure and perhaps production of waste products that could be counterproductive for post-exercise performance (Wilcock et al., 2006). The characteristics of a CWI strategy (temperature, immersion depth, duration and frequency) should therefore be carefully considered to optimise recovery.

Numerous studies have investigated the effects of CWI upon performance, perceptual and physiological recovery. Cold water immersion has been identified to improve post-recovery performance (Kaczmarek, et al., 2013; Kovacs & Baker, 2014; Nédélec et al., 2013; Poppendieck, Faude, Wegmann, & Meyer, 2013), or to have no effect upon performance recovery (Cook & Beaven, 2013; Versey, Halson, & Dawson, 2013) and to detrimentally effect performance recovery (Crowe, O'Connor, & Rudd, 2007). Cold water immersion has also been shown to improve perceptual recovery (Diong & Kamper, 2013; Hohenauer, Taeymans, Baeyens, Clarys, & Clijsen, 2015; Leeder, Gissane, van Someren, Gregson, & Howatson, 2012; Machado et al., 2015), and in contrast to have no effect upon this variable (Crowe et al., 2007; Parouty et al., 2010). Cold water immersion has also been shown to improve the acute inflammatory process from muscle damage (Nédélec et al., 2013), and not improve blood lactate accumulation (Dunne, Crampton, & Egaña, 2013; Parouty et al., 2010; Pointon & Duffield, 2012). Methodological details and the results of studies that investigate CWI are critically appraised and compared in detail in Chapter 2.

1.4 Contrast Water Therapy

Contrast water therapy impacts upon the body in different ways, due to the physiological effects of hydrostatic pressure, cold and hot temperatures of the water immersion. The effects of hydrostatic pressure and the cold temperature have already been discussed in Section 1.2.

The hot component of CWT has the opposing temperature-based effect of CWI in regards to exposure to hot water which increases vasodilation, which in turn increases circulation (Cochrane, 2004) and the supply of oxygen to the muscles (Vaile, Gill, & Blazevich, 2007), which as discussed earlier is a vital component of recovery. The transitions from CWI (vasoconstriction) to hot water (vasodilation) may also cause movement of blood flow in the muscles, leading to attenuation of the immune response and reduce myocellular damage (Vaile et al., 2007). By stimulating circulation, CWT may also cause movement of blood from the extremities due to a decrease in skin temperature and up-regulated sympathetic activity when alternating from hot to cold (Vaile, et al., 2007). The physiological effects that CWT have upon the body may not only affect performance recovery but also perceptual recovery. This is likely due to the hot water component, as passive immersion in warm water has often been reported to have a relaxing, therapeutic effect upon the body (Kovacs & Baker, 2014). According to the gate control theory, warm water stimulates the thermoreceptors which could close the ‘pain gate’ and decrease pain perception (Lane & Latham, 2009). Thermal sensation transmission is faster than pain impulses, thus reducing perceived pain (Lane & Latham, 2009).

A number of systematic reviews have investigated the effect of CWT (Barnett, 2006; Bieuzen, Bleakley, & Costello, 2013; Cochrane, 2004; Hing et al., 2008). Contrast water therapy was reported to improve performance recovery (Bieuzen et al., 2013; Coffey et al., 2004; Crampton, Donne, Warmington, & Egaña, et al., 2013), while in contrast, others report no effect upon performance recovery (Barnett, 2006; Versey et al., 2013; Juliff et al., 2014). Perceptual recovery was found to be improved after CWT (Juliff et al., 2014; King & Duffield, 2009) and also to be unaffected by CWT (Coffey et al., 2004; Juliff et al., 2014; Vaile et al., 2007). Physiological recovery as indicated by lactate post-exercise (Coffey et al., 2004) and thigh volume were found to be decreased after the use of CWT in comparison to a control condition (Vaile et al., 2007). Methodological details and the results of studies that investigate CWT are critically appraised and compared in detail in Chapter 2.

1.5 Active Recovery

Active recovery involves post-exercise low intensity exercise as a 'winding down' mechanism employed by athletes that was initially thought to be effective in reducing post-exercise blood lactate accumulation, due to quicker lactate distribution to the liver for oxidation or reconversion to glycogen, and increased heart and skeletal muscle lactate utilisation (Gisolfi et al., 1966). Active recovery has also been found to sustain post-exercise blood flow (Gill et al., 2006), at a time when passive recovery processes promote reductions in circulatory parameters. Active recovery is usually a weight bearing recovery which may cause more fatigue and decrease recovery perceptions compared to a passive, seated recovery. Furthermore, this in-motion recovery technique may not give athletes the feeling of 'recovery' they are seeking post-exercise. Of concern is that ACT has been found to reduce glycogen resynthesis, likely due to the reliance on these glycogen stores as energy to complete the recovery (Choi, Cole, Goodpaster, Fink, & Costill 1994). Further, it has been suggested that ACT may require additional energy stores (Cochrane, 2004).

Active recovery has been found to improve post-recovery performance (Bielik, 2010; Bogdanis et al., 1996), have no effect upon performance recovery (Barnett, 2006; Nédélec et al., 2013; Stacey, Gibala, Martin Ginis, & Timmons, 2010), and also to inhibit performance recovery (Crampton et al., 2013). Similarly, perceptual recovery has been shown to be improved after ACT (Draper, Bird, Coleman, & Hodgson, 2006), be unaffected by ACT (Crampton et al., 2013), and inhibited after ACT (King & Duffield, 2009). Physiological recovery as measured by lactate was also decreased after ACT (Hudson et al., 1999; Martin et al., 1999) and unaffected by ACT (Stacey et al., 2010). The differences in the effectiveness of ACT may also relate to the duration and intensity of the ACT recovery and the context in which it is used. An ACT recovery of longer duration and higher intensity will potentially use more energy stores and place more stress on the body than a shorter duration and lower intensity ACT recovery. A lengthy ACT could be detrimental if used between events with little recovery time. Methodological details and the results of studies that investigate ACT recovery are critically appraised and compared in detail in Chapter 2.

1.6 Combined Recovery

A COMB recovery combines CWI and ACT, thus a variety of physiological processes are likely to occur. To the authors' knowledge there is currently no conclusive information on the physiological mechanisms of a COMB recovery. However, it is likely to encompass the effects previously discussed for CWI and ACT. As previously discussed hydrostatic pressure increases cardiac output and reduces peripheral resistance. Cold water may also induce peripheral vasoconstriction, which increases venous return, stroke volume, and cardiac output as well as reducing the potential for oedema. Cold water immersion may also assist with perceptions of recovery due to the induced analgesia. The ACT recovery component may also assist with blood lactate removal post exercise due to the increased blood flow to the muscles. All of these processes may work together to provide a recovery that combines the effects of a water immersion and ACT recovery without the strain placed on the body as in a traditional ACT recovery. It has also been suggested in a COMB recovery that hydrostatic pressure may induce an oscillating shift in blood volume due to the movement of the lower limb during COMB (Hudson et al., 1999).

As COMB recovery is relatively new compared to the other recovery strategies discussed above there is limited research available. A combined recovery has been reported to have no effect upon performance recovery (Cortis, Tessitore, Artibale, Meeusen, & Capranica, 2010; Getto & Golden, 2013; Crampton et al., 2014). The combined recovery has also been shown to improve perceptual recovery (Hudson et al., 1999; Kinugasa & Kilding, 2009) and physiologically to be effective at removing blood lactate post-exercise (Ferreira, Da Silva Carvalh, Barroso, Szmuchrowski & Śledziewski, 2011; Hudson et al., 1999). As initial research findings are inconclusive, further research is required to determine the efficacy of the COMB recovery strategy. In summary, equivocal research evidence exists for the effectiveness of each of the above discussed recovery strategies for performance and perceptual recovery, thus further research is required to clarify their effectiveness.

1.7 The Metabolic Demands of Single and Repeated Team Sport Game Play

Many team sport athletes play one competition game a week, while some popular team sports have now also introduced high-intensity condensed competition play, such as rugby sevens (rugby union), rugby league nines (rugby league) and Twenty20 (cricket) tournaments. Both traditional rugby union (one game each week) and rugby sevens (condensed competition game play) schedules impose different types of demands upon the athlete. An analysis of the demands of an elite out-of-season rugby union game (80 min) has shown that rugby union players spend 1% of the time at 0-60% of max HR, 3% at 60-70% of max HR, 15% at 70-80% of max HR, 35% at 80-90% of max HR, 36% at 90-95% of max HR and 10% at 95-100% of max HR (Cunniffe, Proctor, Baker, & Davies, 2009). In the same game players covered 6953 m, expended on average 7.5 MJ of energy and had 118 impacts (total of heavy 7-8 *g*, very heavy 8-10 *g* and severe impacts >10 *g*; average values were calculated from a forward and back position data; Cunniffe et al., 2009). The estimated oxygen consumption throughout a rugby union game was found to be 45.5 ml/kg/min and the average percentage of $VO_{2\ max}$ was 84% (Cunniffe et al., 2009). Relative peak concentric power and jump height have been found to still be reduced 12 and 36 hr after a professional rugby union game (West et al., 2014b), indicating that subsequent performance is impacted upon by prior game fatigue.

During a rugby sevens competitive club-level game approximately 1% of the game was spent at 0-60% of max HR, 2 % at 61-70% of max HR, 14% at 71-80% of max HR, 46% at 81-90% of HR, 28% at 91-95% of max HR and 10% at 96-100% of max HR (Suarez-Arrones, Nunez, Portillo, & Mendez-Villanueva, 2012). Players covered a distance of approximately 1580 m in the 14 min game and had 22 impacts (total of heavy, very heavy and severe impacts as classified earlier; data was calculated from a number of different positions; Suarez-Arrones et al., 2012). Jump height remained reduced at 12 and 60 hr after the last game of the tournament (5 games) for elite rugby sevens players, creatine kinase levels also remained raised throughout the tournament (West et al., 2014a). Unfortunately, research evidence has not yet identified oxygen consumption, average $VO_{2\ max}$ and total energy expenditure in response to a rugby sevens game or a tournament. The number of games in a rugby sevens tournament and the timing of games vary around the world with most competitions consisting of teams playing 5 to 9 games over 2-3 days. If all games in the tournament were played at the same intensity and tactics as the game that was analysed above approximately 7900 m -14, 220 m would be covered and 110-198 contacts made by a rugby sevens athlete in a tournament (36-60 hours approximately; 5-9 games over 2-3 days). In comparison to a tradition rugby union game, it would take rugby sevens athletes five condensed games to cover the same amount of distance covered in a traditional game and six condensed games to reach the same number of impacts.

Rugby union facilitates seven, and rugby sevens five substitutions during a game. Upon comparison of these different types of game play of rugby union (a typical rugby union game and a 2-3 day rugby sevens tournament; including 5-9 games), players have been found to spend a similar amount of time in each HR zone (Suarez-Arrones et al., 2012; Cunniffe et al., 2009). One of the major differences between these game types is the distance covered of 6983 m and 118 contacts in a rugby union game and up to 14, 220 m covered in a rugby sevens tournament and up to 198 contacts. These differences are due to the substantial difference of one 80 min game and 75-135 min cumulated time in a rugby sevens tournament (5-9 shorter games over 2-3 days). Based on the available load data, once rugby sevens players have competed in 6 games within a tournament weekend they will have exceeded the physical load associated with a traditional game. Perhaps the most important difference between the two types of competitions is the recovery time. A rugby sevens tournament requires players to be able to play games back to back in a short period of time (games approximately 3 hr apart during a tournament day over 2-3 days). Whereas after a rugby union game, players are not normally required to play another game for a number of days and will normally commence a training session the following day.

This may have implications for recovery when the number of impacts is considered. If an athlete competes at the higher end of the scheduled rugby sevens games in a tournament, the higher number of impacts compared to the 80 min game would likely contribute to greater muscle damage, bruising, oedema and fatigue experienced by players and therefore reduced physical performance in each consecutive game over the tournament days.

Due to the intensity and nature of rugby union and that jump variables were still decreased 12 hr and 36 hr (traditional) and 12 hr and 60 hr (rugby sevens) after performance it is vital that an effective recovery strategy be utilized by players. Due to the high number of impacts in both a traditional rugby union format and rugby sevens, CWI recovery strategies may be beneficial to help reduce oedema and enhance subsequent game play and training. In contrast, an ACT recovery after each game in a rugby sevens tournament may utilize energy stores, whereas after a single rugby union game it may still be an effective recovery option.

Perceptual recovery is of high importance for all athletes, especially those that play rugby sevens with limited time between games. A water immersion recovery may assist with this perceptual recovery, specifically by inducing analgesia. A non-weight bearing recovery such as water immersion may also assist with the reduction of fatigue experienced by players. In contrast, an ACT recovery after each game in a rugby sevens tournament may induce feelings of fatigue in players, whereas after a single rugby union game it may still be an effective recovery option.

In summary there are potential differences between the demands of a single rugby union game and a rugby sevens competition, depending on the number of games played in the rugby sevens competition. The difference in the time available to recover is the key difference. The rugby sevens athlete plays numerous games in a short time span and therefore require rapid recovery, whereas the traditional rugby union game athlete will play one game per week and therefore may have a schedule that allows for a more gradual (e.g. 24 hr) recovery. Thus it is imperative that the use of recovery strategies during these two types of competition are analysed separately.

1.8 Statement of the Problem

Although anecdotally many athletes undertake post-exercise recovery, to the authors' knowledge there is currently no published research available about the use of recovery strategies by Australian athletes. Thus further investigation into the use of recovery strategies by Australian athletes is warranted. The contrasting results of recovery strategies also show that more research is needed to compare CWI, CWT, ACT, COMB and CONT.

Furthermore, while water immersion strategies are anecdotally viewed by athletes and coaches to be more frequently used and more effective than ACT, there is little research that compares the water immersion strategies to ACT and CONT to identify the superior recovery strategy for performance and perceptual recovery after a single bout of fatiguing exercise and during and after repeated shorter bouts of exercise. As summarised earlier, differing performance and perceptual outcomes have resulted from CWI, CWT, COMB and ACT use post-exercise with no conclusive evidence to suggest the use of one recovery strategy over another.

1.9 Aims and Hypotheses

This thesis will investigate the effectiveness and athlete use of post-exercise recovery strategies. The research presented in this thesis seeks to firstly critically review and analyse studies that investigate water immersion compared to the effect of active recovery, and no recovery. Secondly, it will identify the use of various recovery strategies and reasons for use or disuse by male and female team sport athletes of varying competition levels within Australia. Thirdly, this thesis aims to investigate the effectiveness of CWI, CWT, ACT, COMB and CONT after a single bout of fatiguing exercise with respect to performance and perceptual recovery indices over a 48 hr period. Fourthly, the use of CWI, CWT, ACT, COMB and CONT during a simulated repeated games setting upon performance, perceptual and physiological indices of recovery over an 8 hr period will be examined. This thesis seeks to identify how and why recovery is used in Australia and if there is a superior recovery method for performance and perceptual recovery indices after a single bout of fatiguing exercise and throughout a repeated exercise setting.

This thesis will test the following five hypotheses:

1. The majority of athletes will self-report the use of one or more recovery strategies following games/training.
2. Stretching will be the most popular choice (i.e. most often used) reported in the survey by all levels of athlete, due to the convenience of this recovery strategy and its availability to be used in a team situation.
3. Cold water immersion and CWT will be considered the most effective recovery strategies by surveyed athletes, due to the high anecdotal use of these recovery strategies by elite athletes.
4. Water immersion strategies and ACT will be superior to CONT for performance and perceptual indices of recovery after a single bout of fatiguing exercise, based on current available evidence.
5. Water immersion strategies will be superior to ACT and CONT for performance and perceptual indices of recovery during a repeated game tournament setting, based on current available evidence.

1.10 Thesis Format

This thesis comprises the following six chapters: an introduction, systematic review, three research projects and discussion with conclusions. The systematic review (Chapter 2) will analyse and synthesise research outcomes in the area of water immersion and ACT strategies upon performance and perceptual recovery following a single bout of fatiguing exercise and during a day of repeated exercise. The three research project chapters designed on the basis of the systematic review outcomes will then address the aims and hypotheses of the thesis. These chapters (3-5) are presented for publication and thus common themes occur throughout the introduction and discussion of these chapters. Specifically, Chapter 3 will investigate the use and perceptions of recovery in Australian team sport athletes. The fourth Chapter will investigate the effect of CWI, CWT, ACT, COMB and CONT after a single bout of fatiguing exercise on performance, flexibility and perceptual recovery over a 48 hr time period. Chapter 5 will investigate the effect of CWI, CWT, ACT, COMB and CONT during a simulated repeated game tournament setting upon performance, perceptual, flexibility and physiological recovery. These individual research projects will be synthesised in a discussion that combines, compares and contrasts all of the thesis findings and will conclude with practical applications from the research, limitations of the research, and recommendations for future research.

1.11 Scope of the Thesis

The protocols used in this thesis are based on published research. Although a large number of variables have been utilised to investigate recovery effectiveness, the scope and associated limitations need to be considered when reviewing the findings of this thesis. The research conducted in this thesis is mainly based on a northern Australian sample, and the RCTs (Chapters 4 and 5) use simulated team sport fatiguing exercise in lieu of actual sports competition to assist with research design controls. The systematic review conclusions are limited due to the large variety of fatiguing exercises, recovery protocols, testing variables, time points and statistical analyses of the included articles. Chapter 3 is based on the assumption that participants' responses are accurate and are not influenced by other athletes who were completing the survey at the same time. There is also potential that participants misinterpreted information, however checkbox and free-text response comparisons were performed to confirm response consistency. While five competition levels were represented in the survey sampling, most athletes were based in northern Queensland and therefore results are indicative of that region, and may not represent the whole of the country despite all included sports being contested broadly throughout Australia. Chapter 4 investigated selected performance and perceptual outcomes that have been used in prior research, but no physiological outcomes were investigated. Chapter 5 included the variables that were investigated in Chapter 4, with blood lactate samples also taken at a restricted number of time points. The testing of variables in Chapter 5 took place across repeated bouts of simulated rugby sevens bouts, not at a rugby sevens event in order to control the protocols; therefore outcomes are indicative of tournament play. While the survey research included females, both Chapters 4 and 5 included assessment of male participants only and therefore may not represent female athlete physical, physiological and perceptual recovery responses.

1.12 Significance of this Study

This thesis critically analyses research that investigates water immersion strategies and ACT recovery strategies upon performance and perceptual outcomes, to identify if one of the anecdotally used recovery strategies is superior for performance and perceptual recovery. It is the first study to capture the team sport athlete perspectives from multiple competition levels of when, why or why not, how and which recovery strategies are undertaken after competition and training in Australia. It also provides insight into whether athletes understand the mechanisms of the recovery strategies they routinely undertake. This thesis will report recommendations from unique RCT research that compares and contrasts a number of popular recovery strategies (CWI, CWT, ACT, COMB and CONT) to identify which recovery should be used following team sport fatiguing exercise over a 48 hr period as well as during a repeated small-sided game setting such as a tournament day. This thesis will provide high quality research findings to assist team sport athletes and coaches to make more informed decisions regarding recovery use post-game and during a tournament day.

Chapter 2

A Systematic Review of the Effects of Cold Water Immersion, Contrast Water Therapy and Active Recovery on Performance and Perceptual Recovery

2.1 Abstract

A range of strategies are commonly used to achieve fast recovery from exercise, yet there is very little systematic and comparative evidence to support the effectiveness of one recovery strategy over another.

Literature searches were conducted using eleven electronic databases. Journal articles published between 1960 and 2017 were assessed for inclusion. Performance and perceptual results of CWI, CWT, ACT and CONT were analysed at all time points during and post recovery. Methodological quality of the included articles was assessed using the PEDro scale.

Thirty-seven articles were included in the systematic review. The articles were of limited or moderate methodological quality. Mostly, CWI, CWT, ACT and CONT were found to be no different to CONT for performance and perceptual recovery. Contrast water therapy was found to be superior to CONT more often than CWI and ACT for performance. For perceptual recovery CWI and CWT improved perceptual recovery in comparison to CONT at 27% of time points, with no decreases in comparison to CONT. Active recovery did not improve perceptual recovery in comparison to CONT at any time point, with mostly no difference between the two indicated.

There is currently little clear evidence to suggest the use of one recovery over another for performance and perceptual recovery after exercise. However, this systematic review shows based upon limited-moderate quality research that CWT is superior to CONT or just as effective and is not detrimental to performance and perceptual recovery. It is recommended

that further high quality research be undertaken that compares the four recovery strategies to clarify their effectiveness upon performance and perceptual recovery.

2.2 Introduction

Many team sport athletes play one competition game a week, while some popular sports have now also introduced high-intensity condensed competition play, such as Rugby sevens (rugby union), Auckland nines (rugby league) and Twenty20 (cricket) tournaments. Rugby sevens includes 5-9 shortened rugby union games (2 x 7 min halves) over 2-3 days, Auckland nines includes 3-6 games (2 x 9 min halves) over 2 days and Twenty20 cricket is a single event which takes up to 3 hr. Both the traditional and condensed format competitions require recovery between games for players to perform at their best; however very limited research has investigated the effects of recovery strategies during these types of game play, particularly in the case of repeated games. Research is predominantly focused upon the effect of a single bout of recovery after fatiguing exercise (Coffey et al., 2004; Crampton, Donne, Egaña, & Warmington, 2011; Crampton et al., 2013).

If a recovery strategy is not undertaken or a suboptimal recovery strategy is undertaken, athletes could be more susceptible to injury and fatigue, and less likely to be able to perform at their best (Barnett, 2006; Hing et al., 2008). Muscle swelling (oedema) and DOMS may also occur without effective recovery (Zainuddin, Newton, Sacco, & Nosaka, 2005). Delayed onset muscle soreness induces a number of symptoms such as muscle tenderness, debilitating pain and a reduction in joint range of motion (Cheung et al., 2003). Delayed onset muscle soreness may occur due to microscopic tears in the muscle fibers or connective tissues, which results in limb swelling, cellular degradation and an inflammatory response causing pain in the 24-48 hr following strenuous exercise (Powers & Howley, 2004).

To reduce DOMS, fatigue and risk of injury athletes often undertake recovery routines. There are many post-exercise recovery options currently available for athletes. Some of these include water immersion, STR, ACT, swimming or pool walking, massage, sleeping/napping and fluid/food replacement (Halson, 2013; Hing, White, Lee, & Boouaphone, 2010; Venter et al., 2010). Anecdotally water immersion, STR and ACT are recovery strategies often undertaken by team sport athletes as they are able to be implemented after training and as an entire team.

2.2.1 Active recovery. Active recovery has been a popular and practical method of recovery for many years. The earliest study that investigated ACT was conducted by Gisolfi and colleagues in 1966. This study reported that running on a treadmill at participants' oxygen consumption steady state and oxygen debt steady state for 35-50 min enhanced lactate removal and decreased oxygen debt after exercise in comparison to CONT (Gisolfi et al., 1966). An ACT recovery was a more effective recovery technique than CONT for performance 4 min post the initial exercise bout (Bogdanis et al., 1996), and for blood lactate removal 10-25 min post exercise (Martin et al., 1998; Hudson et al., 1999), 36 and 84 hr post exercise for percentage of recovery based on creatine kinase levels (Gill et al., 2006). The proposed mechanisms for improved performance after ACT is enhanced rate of lactate removal via quicker lactate distribution to the liver, increased heart muscle and skeletal muscle lactate utilisation (Gisolfi et al., 1966), increased blood flow and range of motion (Gill et al., 2006). Active recovery at 40% of peak running speed for 15 min has also been shown to not improve muscle soreness or performance 4 hr post initial exercise in comparison to CONT (Coffey et al., 2004). Active recovery has also been shown to be detrimental to immediate repeated maximal cycling sprint performance recovery in comparison to CONT (Spencer, Bishop, Dawson, Goodman, & Duffield, 2006) and to increase RPE in repeated exercise in comparison to CONT (King & Duffield, 2009). Active recovery may be detrimental to performance recovery, because it may reduce glycogen resynthesis due to its potential reliance on glycogen for energy (Choi et al., 1994) and because ACT may require additional energy stores (Cochrane, 2004). Perceptual recovery after ACT may be decreased due to the weight bearing nature of this type of recovery. In summary, there is conflicting research regarding the effectiveness of ACT as a recovery strategy for performance and perceptual recovery post exercise.

2.2.2 Cold water immersion. Cold water immersion recovery strategies became popular during the late 1990's (Eston & Peters, 1999). Eston and Peters (1999) reported that CWI of the arm reduced creatine kinase levels, and increased relaxed elbow angle by reducing the extent of muscle and connective tissue shortening after exercise. However, muscle tenderness, swelling and strength loss were unaffected by CWI and thus the authors recommended further research into this recovery strategy (Eston & Peters, 1999). More recent research has shown CWI to be more effective at maintenance than CONT for quadriceps strength (24 hr post fatiguing exercise); for quadriceps and calf DOMS at 24 hr post fatiguing exercise; and adductor DOMS at 30 min post fatiguing exercise (Ascensããо, Leite, Rebelo, Magalhääes, & Magalhääes, 2011). In contrast, other studies have shown CWI to reduce cycling peak power and total work in comparison to CONT (1 hr post fatiguing exercise; Crowe, et al., 2007) and to have the same effect as CONT upon cycling measures (9 hr post fatiguing exercise) and perceptions of physical and mental recovery, prior to a second bout of fatiguing exercise (9 hr post fatiguing exercise; Rowsell, Reaburn, Toone, Smith, & Coutts, 2014). Recent reviews of CWI have found somewhat positive results, with Machado and colleagues (2015) reporting CWI to be slightly better than CONT for managing muscle soreness; Versey and colleagues (2013) finding CWI to improve exercise performance in comparison to thermoneutral water immersion; and Diong and Kamper (2013) reporting that CWI reduced DOMS in comparison to CONT. The common analgesic effects reported for

CWI (Jakeman, Macrae & Eston, 2009) may be due to a reduction in neuron transmission speed within the body which may also decrease pain (Meeusen & Lievens, 1986). These analgesic effects would assist athletes with post exercise perceptual recovery. Machado and colleagues (2015) state that CWI as a recovery strategy causes vasoconstriction and redirection of blood flow. Kovacs and Baker (2014) also state that the hydrostatic pressure placed on the body during CWI can also help reduce oedema and muscle damage experienced by athletes by causing a fluid shift. Hydrostatic pressure also causes a rise in blood pressure and central blood volume which increases the clearance of waste products (Kovacs & Baker, 2014). The buoyancy component of CWI may also reduce fatigue by reducing the gravitational forces on the body, resulting in potential reduced neuromuscular activation and conservation of energy (Wilcock et al., 2006). All of these components of a CWI recovery strategy would be of benefit to performance and perceptual recovery for athletes post-exercise. In contrast CWI may be detrimental due to a potential increase in metabolism (Wilcock et al., 2006) and oxygen consumption (Ishan et al., 2016) if shivering commences. In summary, CWI has been shown to have differing effects upon performance and perceptual recovery.

2.2.3 Contrast water therapy. Contrast water therapy was first reported in scientific literature by Kuligowski and colleagues in 1998. This study found both CWT (6 cycles of 3 min in 38.9 ºC and 1 min in 12.8 ºC) and CWI (24 min at 12.8 ºC) returned participants to baseline values of resting elbow flexion faster and lowered perceived soreness significantly more than CONT (Kuligowski et al., 1998). No difference was found between CWT and CONT for treadmill run time to exhaustion and perceptions of recovery in highly active males (Coffey et al., 2004). Contrast water therapy has also been found to improve cycling peak power, total work and exercise time to failure (Crampton et al., 2011). In response to the growing availability of contrasting research, several reviews have been published that investigate CWT (Bieuzen et al., 2013; Cochrane, 2004; Hing et al., 2008). Two of these reviews have not been able to conclude whether CWT is an effective recovery method following exercise and sport (Cochrane, 2004; Hing et al., 2008). In comparison, Bieuzen and colleagues (2013) found CWT to improve performance and perceptions of recovery. Contrast water therapy imparts the physiological effects of both CWI and hot water immersion. As discussed earlier the hydrostatic component of the water immersion may increase cardiac output and reduce peripheral resistance, it may also reduce neurotransmitter activity and oedema. The cold component may induce peripheral vasoconstriction, which increases venous return, stroke volume and cardiac output as well as induce analgesia. The hot component may increase vasodilation, which increases circulation (Cochrane, 2004) and the supply of oxygen to the muscles (Vaile et al., 2007) enhancing performance. The hot water component may also have a relaxing, therapeutic effect upon the body (Kovacs & Baker, 2014). Further warm water stimulates the thermoreceptors which send a signal to the brain faster than the pain receptors, which is potentially why warm water reduces perceived pain (Lee et al., 2013). Further, according to the gate control theory, warm water will stimulate the thermoreceptors which could close the 'pain gate' and reduce pain perception (Lane & Latham, 2009). Atkinson and colleagues (2006) also suggest that hot water may cause modulation of pain receptors in the nervous system, decreasing experienced pain. These mechanisms will assist with perceptual recovery. Based on the literature, the effectiveness of CWT as a recovery strategy is still to be determined.

In summary, the recovery strategies discussed above have varying physiological effects upon the body. An ACT recovery requires the athlete to continue moving and expending energy, and so although it may assist with lactate removal, it may also reduce glycogen resynthesis and energy stores. Perceptually, ACT does not always allow athletes to feel as though they are having a 'rest' after exercise. In contrast the water immersion strategies are static and have the physiological and perceptual effects attributed to hydrostatic pressure and temperature. There is no clear evidence as to which of these recovery strategies is most effective and thus the need for further research.

To the authors’ knowledge, no systematic review has been published that compares the effectiveness of ACT, CWI, CWT and CONT with respect to post-exercise recovery. Therefore the aim of this review is to systematically compare ACT, CWI, CWT and CONT to determine whether water immersion strategies (CWI and CWT) are more beneficial than ACT or CONT for performance and perception-based recovery variables.

2.4 Methods

2.3.1 Eligibility criteria and study selection. An electronic database search was conducted by two authors independently during 2012 and again during 2013, and by the principal author again in 2016 and 2017 using the following databases: Medline, Pubmed, Sports Discus, Cochrane, Pedro, Cinahl, Informit, Scopus, Cab Direct, Web of Science and Google Scholar (Figure 2.1). Database searching was undertaken using the following key terms alone or in combination: 1. post sport recovery; 2. methods; 3. psychology; 4. interventions; 5. performance; 6. water immersion; 7. cold; 8. cold treatment; 9. exercise; 10. contrast; 11. water therapy; 12. simulated team collision sport; 13. team sport; 14. hydrotherapy. Each of these terms and combinations of terms was first searched using quotation marks around each phrase. If results were not found using quotation marks, they were removed to broaden the search. Titles followed by abstracts were read for the initial inclusion/exclusion process. This was followed by a second exclusion round where the full articles were reviewed (Figure 2.1).

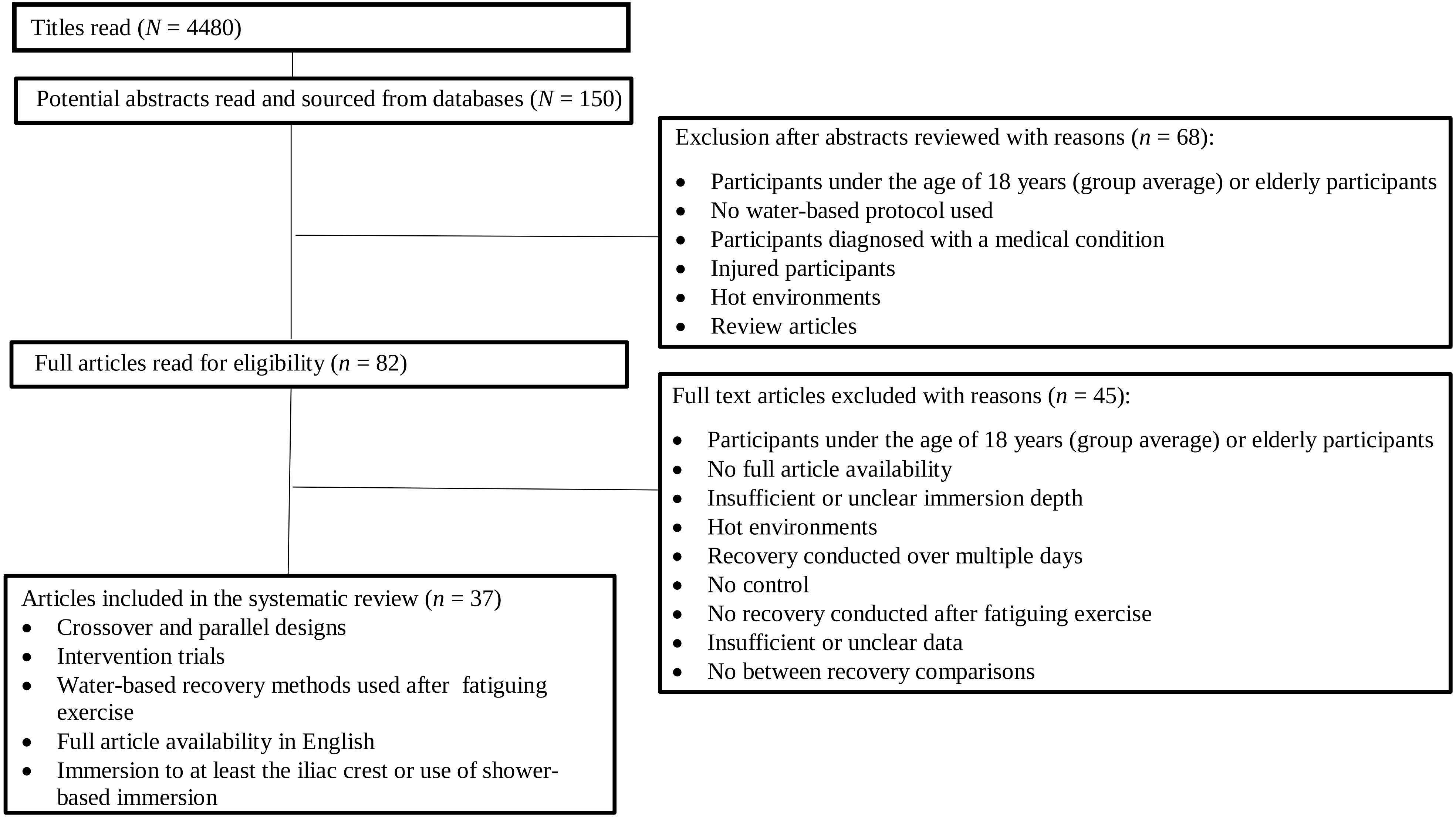

Figure 2.1. Flow diagram of the inclusion and exclusion process for selecting articles to be included in the systematic review.

2.3.2 Methodological quality assessment. The methodological quality of the articles that met the inclusion criteria was assessed using the modified Physiotherapy Evidence Database (PEDro) scale (Hing et al., 2008). The PEDro scale is a technique used to assess the methodological quality of an RCT (Hing et al., 2008). Usually, in order to examine the quantitative methodological quality of an article, seven of the eleven items (item numbers: 2, 3, 5-9) of the PEDro scale are added together to formulate an Internal Validity Score (IVS) with associated quality levels (Table 2.1, modified from Hing et al., 2008). In this study three of the items (item numbers: 3, 5 and 9: concealed allocation, blinding of subjects and intention to treat analysis) have been removed from the scoring process, to provide a more accurate representation of the quality of the articles. Items 3 and 5 have been removed as it is not possible to conceal allocation of recovery type or blind subjects to water immersion and water temperature. In removing these items the author acknowledges that particular studies that have implicated the placebo effect (Broatch, Peterson, & Bishop, 2014) may be underscored. Item 9 has been removed as the nature of the study does not allow for intention to treat analysis. Because of the exclusion of three criteria, the IVS for each article has been modified as per Table 2.1 so that the PEDro Internal Validity Score can be used.

2.3.3 Included article review. Included articles in this evaluation were all intervention trials utilising healthy adult participants. The methodological approaches and results of the 37 included articles have been summarised in Table 2.3. The papers included in this systematic review were analysed under the following headings; study and population characteristics, characteristics of the fatigue inducing exercise protocols, characteristics of CONT, CWI, CWT and ACT protocols, the effect of CWI, CWT and ACT on performance and the effect of CWI, CWT and ACT on perceptual recovery. All time points are considered to be after exercise unless stated and time points before recovery are not analysed. Recovery strategies that were undertaken in the included articles that are not CWI, CWT, ACT or

CONT were not included. Only performance and perceptual variables related to recovery were included in the systematic review and can be viewed in Table 2.2. Performance variables test the athlete's ability to perform a particular skill or use an energy system, usually maximally. Perceptual variables are related to the athlete's thoughts and perceptions about their recovery. As this is a systematic review, all data presented in Table 2.3 was extracted from the included papers. Data pooling for meta-analysis was not undertaken due to the diversity of the exercise protocols, recovery strategies and data representation. Significant *p* values and moderate to large effect sizes were considered significant results and the direction of change has been reported.

2.5 Results

2.4.1 Methodological quality assessment. According to the PEDro quantitative methodological quality scoring system and the modified IVS rating, all of the articles included in the systematic review were of limited or moderate methodological quality (Table 2.1). Cook and Beaven (2013) and Rowsell and colleagues (2014) were both assigned a limited rating (2/8) due to no recognition of random allocation (Cook and Beaven, 2013 only), baseline comparability, blinding of therapists, blinding of assessors, insufficient data collection and insufficient variability and point measures (Rowsell et al., 2014 only). Delextrat and colleagues (2012), Fonseca and colleagues (2016), Garcia and colleagues (2016), Getto and Golden (2013), Parouty and colleagues (2010), Sellwood and colleagues (2007), Takeda and colleagues (2014), Yeung and colleagues (2016) all scored moderate ratings, with the highest score of 5/8. Most articles did not meet the criteria of blinding of therapists (100%), blinding of assessors (95%) or adequate data collection (76%).

2.4.2 Study and population characteristics. A total of 37 articles met the inclusion criteria. The total population of the 37 studies was 620 healthy, non-injured participants; 80% of the participants were male, 18% female and 2% the gender was unspecified. The average

age was 23 years (range 18-30 years) and the average number of participants per study was 17 (range 7-41). A large proportion of participants were team sport athletes (31%), followed by active participants (23%), volunteers (22%), individual sport athletes (16%) and well/highly trained participants (8%).

Table 2.1

PEDro quantitative methodological quality scores (adapted from Hing et al., 2008) for the 37 articles included in the systematic review.

Author	1.	2. (IVS item)	4.	6. (IVS item)	7. (IVS item)	8. (IVS item)	10.	11.	12	13	14
Argus et al. (2016)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
Ascensããо et al. (2011)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
Bailey et al. (2007)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2
Broatch et al. (2014)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2
Brophy-Williams et al. (2011)	✓	X	X	X	X	✓	✓	✓	3	Limited	2
Cengiz and Kovak (2016)	X	X	✓	X	X	X	✓	✓	3	Limited	0
Cook and Beaven (2013)	X	X	X	X	X	X	✓	✓	2	Limited	0
Coffey et al. (2004)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
Corbett et al. (2012)	X	✓	✓	X	X	X	✓	X	3	Limited	2
Crampton et al.(2011)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2
Crampton et al. (2013)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2
Crowe et al. (2007)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
Delextrat et al. (2012)	✓	✓	✓	X	X	✓	✓	✓	5	Moderate	4
Dunne et al. (2013)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2
Elias et al. (2012)	✓	X	✓	X	X	✓	✓	✓	4	Moderate	2
Elias et al. (2013)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
Fonseca et al. (2016)	✓	✓	✓	X	X	✓	✓	✓	5	Moderate	4
French et al. (2008)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2
Garcia et al. (2016)	✓	✓	✓	X	✓	X	✓	✓	5	Moderate	4
Getto et al. (2013)	✓	✓	✓	X	X	✓	✓	✓	5	Moderate	4
Jakeman et al. (2009)	✓	✓	✓	X	X	X	✓	X	3	Limited	2
Juliff et al. (2014)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
King and Duffield (2009)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
McCarthy et al. (2016)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2

Parouty et al.(2010)	✓	✓	✓	X	X	✓	✓	✓	5	Moderate	4
Pointon and Duffield (2012)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
Pournot et al. (2011)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2
Rowsell et al. (2014)	✓	✓	X	X	X	X	✓	X	2	Limited	2
Schniepp et al. (2002)	✓	✓	✓	X	X	X	✓	X	3	Limited	2
Sellwood et al. (2007)	✓	✓	✓	X	✓	X	✓	✓	5	Moderate	4
Stacey et at al. (2010)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2
Stanley et al. (2012)	X	✓	X	X	X	✓	✓	✓	4	Moderate	4
Stanley et al. (2014)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
Takeda et al. (2014)	X	✓	✓	X	X	✓	✓	✓	5	Moderate	4
White et al. (2014)	✓	✓	✓	X	X	X	✓	✓	4	Moderate	2
Vaile et al. (2007)	X	✓	✓	X	X	X	✓	✓	4	Moderate	2
Yeung et al. (2016)	X	✓	✓	X	X	✓	✓	✓	5	Moderate	4

Note. 1. Eligibility criteria; 2. Random allocation; 4. Baseline comparability; 6. Blinding of therapists; 7. Blinding of assessors; 8. Adequate data collection; 10. Between group comparisons; 11. Variability and point measures; 12. Quality score (not including criteria 1); 13. Modified internal validity score 14. Modified methodological quality score (criteria 2, 6-8)

Table 2.2

Performance and perceptual variables assessed in the included systematic review articles

Performance variables	Perceptual variables
Yo-yo intermittent recovery test	Total quality recovery (TQR)
Repeated sprint ability (RSA)	Subjective impressions of recovery
50 m sprint	Perceptions of physical and mental recovery
Repeated agility	Rating of perceived recovery
Side steps for 20 sec	Rating of recovery intervention
Vertical jump (VJ), countermovement jump (CMJ), squat jump (SJ) and drop jump (DJ)	Recovery effectiveness perceptions
Neuromuscular function	Muscle soreness (MS)
Cycling measures	Leg soreness
Reaction time	Ratings of perceived soreness
Fatiguing exercise	Perceived soreness and perceived fatigue
	Overall/whole body/general fatigue
	Perceived impairment
	Quadriceps muscle pain
	Rating of perceived exertion (RPE)
	Rating of perceived exertion recovery
	Motivation
	Effort

Table 2.3

Study characteristics and outcomes of the articles included in the systematic review (n = 37).

Author (year)	Participants	Exercise protocol used to induce fatigue	Interventions (water immersion, CONT and/if ACT; full body immersion excludes head and neck)	Variables investigated (performance and perceptual)	Timing of measures (time post fatiguing exercise)	Results ES, p value, CI/ CL * = 90% and ^ = 95%) between recovery strategies for performance and perceptual variables
Argus et al. (2016)	13 male volunteers, average age 26 years.	50 min resistance training protocol.	CWI- full body immersion for 14 min at 15 ºC. CWT- 7 cycles of 1 min in 15 ºC and 1 min in 38 ºC. CONT- 14 min seated at 23 ºC.	MVC, bodyweight and 40CMJ, perceived soreness and fatigue.	All measures (5 min, 2 and 4 hr post recovery).	No significant recovery x time differences for MVC (ES = 0.06), bodyweight CMJ height (ES = 0.10), mean velocity (ES = 0.02) or mean force (ES = 0.04). A significant recovery x time difference for 40CMJ height, however no difference between recovery groups. No significant recovery x time differences for 40CMJ mean velocity (ES = 0.08) and mean force (ES = 0.08). No significant recovery x time differences for soreness (ES = 0.06) and fatigue (ES = 0.05).
Ascensão et al. (2011)	20 male national league junior soccer players, average age 18 years.	Friendly soccer match.	CWI- immersion to the iliac crest for 10 min at 10 ºC. CONT- 10 min immersion in 35 ºC thermoneutral water.	SJ, CMJ, 2 x 20 m maximal sprints, quadriceps strength and MS questionnaire.	All measures (within 30 min 24 and 48 hr post).	No significant differences for SJ, CMJ and sprint performance. Quadriceps strength was significantly higher after CWI at 24 hr in comparison to CONT, but no differences at any other time point. Quadriceps and calf DOMS after CWI was significantly reduced at 24 hr in comparison to CONT. Hip adductors DOMS after CWI was also significantly reduced at 30 min post in comparison to CONT; no other DOMS differences.
Bailey et al. (2007)	20 male habitually active participants, average age 22 years.	Loughborough intermittent shuttle test.	CWI- immersion to the iliac crest for 10 min at 10 ºC. CONT- 10 min seated.	MVC, VJ, sprint performance and perceived MS.	MVC and VJ (24, 48 and 168 hr), sprint performance (48 hr post) and perceived MS (1, 24, 48 and 168 hr post).	MVC improved after CWI in comparison to CONT at 24 and 48 hr post, with no difference at any other time point. No significant difference was found for VJ and sprint performance. Perceived MS was significantly less after CWI at

						1, 24 and 48 hr post exercise in comparison to CONT, but not at 168 hr post.
Broatch et al (2014)	30 male recreationally active participants, average age 24 years.	20 min acute high-intensity interval training.	CWI- immersion to the umbilicus for 15 min at 10 ºC. CONT- 10 min immersion in 35 ºC thermoneutral water.	MVC, quadriceps pain threshold and tolerance, perceptual questionnaire and belief questionnaire.	MVC, pain threshold and tolerance measures of the quadriceps, perceptual questionnaire (immediately post recovery, 1, 24 and 48 hr post), and belief questionnaire at the conclusion of testing.	No differences for MVC, quadriceps pain threshold and tolerance. Physical readiness to exercise was higher after CWI vs CONT immediately post recovery, 1 and 24 hr post. Mental readiness and vigor was also increased after CWI vs CONT immediately post recovery and 1 hr post. Sleepiness perceptions was improved after CWI vs CONT immediately post recovery (ES > 0.8). No other differences for the perceptual questionnaire or the belief questionnaire.
Brophy-Williams et al. (2011)	8 male Australian Football League players, average age 20 years.	8 x 3 min intervals of running at 90% of $\dot{V}O_2max$ velocity, with 1 min passive rest between intervals.	CWI- immersion to the mid-sternum for 15 min at 15 ºC. CWI 3 hr- immersion to the mid-sternum for 15 min at 15 ºC performed 3 hr after the completion of fatiguing exercise. CONT- 15 min seated at 23 ºC.	Yo-yo intermittent recovery test, TQR and MS.	All measures (24 hr post).	Significant main effect of recovery for yo-yo test shuttles (p = 0.01), with the average number of shuttles significantly more after CWI vs CONT (ES = 0.8, p = 0.02). No difference between CWI 3 hr vs CONT (ES = 0.5, p = 0.06) and vs CWI (ES = 0.3, p = 0.12). For TQR there was a main effect of recovery, with ratings lower after CONT vs CWI and CWI 3 hr (p = 0.02). For MS no significant main effect for recovery was calculated (p = 0.11).
Cengiz et al. (2016)	20 male elite wrestlers, average age 23 years.	60 min vigorous wrestling training session.	CWI- immersion of the whole body for 10 min at 10 ºC. CONT- 10 min immersion of the whole body at 35 ºC.	VJ or rope climb time.	VJ or rope climb time (30 min and 24 hr post)	VJ and rope climb time at both time points was improved after CWI vs CONT.
Cook and Beaven, (2013)	12 male semiprofessional rugby union players, average age 23 years.	60 min high-intensity gym and track-based conditioning session.	CWI- immersion to the ASIS for 15 min at 14 ºC. CONT- 15 min seated at 20 ºC.	5 x 40 m maximal sprints and rating of recovery intervention.	5 x 40 m maximal sprints (24 hr post), and rating of recovery intervention (within 5 min post intervention).	The fifth sprint of the maximal sprints was significantly faster following CWI vs CONT (ES = 1.06, CL* = 0.68). Performance maintenance in the 5 x 40 m maximal sprints after CWI was significantly improved vs CONT (ES = 1.44, CL* = 0.84). A large linear correlation (r = 0.5886; p = 0.04) was calculated between rating of recovery intervention and performance maintenance. No differences were identified between CWI vs CONT for rating of recovery intervention (ES =

						0.49, CL* = 0.68). No other calculations were significant.
Coffey et al. (2004)	14 male highly active participants, average age 26 years.	120% and 90% peak running speed treadmill runs to exhaustion with a 15 min rest between.	CWT- immersion to the ASIS, 5 cycles of 1 min in 10 ºC and 2 min in 42 ºC. ACT- 15 min run at 40% of peak running speed. CONT- standing for 15 min.	Repetition of fatiguing exercise, rating of RPErec.	Repetition of fatiguing exercise (4 hr post) and RPErec- (immediately and shortly after recovery, before and immediately after fatiguing exercise bout 2).	No significant differences.
Corbett et al. (2012)	40 male volunteers, average age 20 years	Loughborough intermittent shuttle test	CWI- immersion to the umbilicus for 12 min at 12 ºC. CWI- immersion to the umbilicus for 2 min at 12 ºC. ACT- 12 min walking at 5km/hr. CONT- 12 min umbilicus immersion in 35 ºC thermoneutral water.	MVC, hop test and MS.	MVC and hop test (24, 48, 72 and 168 hr post recovery) and MS (1, 24, 48 72 and 168 hr post recovery).	No significant differences.
Crampton et al. (2011)	16 male amateur football players, average age 24 years.	3 x 30 sec Wingate, separated by 4 min of cycling at 50 W or 40% max power cycling for 30 sec followed by 120% max power for 30 sec, repeated until exhaustion.	CWT- immersion to the iliac crest, 6 cycles of 2.5 min at 8 ºC and 2.5 min at 40 ºC. CWT- immersion to the iliac crest, 6 cycles of 1 min at 8 ºC and 4 min at 40 ºC. CONT- 30 min seated at 21 ºC.	Repetition of fatiguing exercise (fatiguing exercise 2).	Fatiguing exercise 2 (35 min post).	Wingate protocol: peak power and total work during fatiguing exercise 2 increased after CWT (6 cycles of 1 min at 8 ºC and 4 min at 40 ºC) vs CONT. Peak power and total work was not different between CWT protocols or between CWT (6 cycles of 2.5 min at 8 ºC and 2.5 min at 40 ºC) vs CONT. Repeated intermittent sprint: exercise time to failure and total work during fatiguing exercise 2 was increased after both CWT protocols vs CONT, with no difference between the CWT protocols.
Crampton et al. (2013)	9 male club-level trained triathletes, average age 30 years.	Submaximal exhaustive cycling bout: 5 min at ~50% $\dot{V}O_2$ peak, followed by 5 min at ~60% $\dot{V}O_2$ peak and then ~80% $\dot{V}O_2$ peak to exhaustion.	CWI- hip height immersion for 30 min in 15º C. CWT- hip height immersion, 6 cycles of 2.5 min at 8 ºC and 2.5 min at 41 ºC. ACT- cycling at 40% of $\dot{V}O_2$ peak for 30 min.	Repetition of fatiguing exercise (fatiguing exercise 2).	Fatiguing exercise 2 (40 min post).	Time to failure during fatiguing exercise 2 was longer in CWI than in CWT, CONT and ACT (ES > 0.8) and longer after CWT than after ACT (ES = 0.5-0.79). The percentage change from fatiguing exercise 1 to 2 was significantly smaller after CWI vs CWT, ACT and CONT (ES > 0.8) and also smaller in CWT vs ACT and CONT (ES = 0.5-0.79).

			CONT- 30 min immersion in 34 ºC thermoneutral water.			
Crowe et al. (2007)	17 (13 male, 4 female) active participants, average age 22 years.	30 sec max cycling test.	CWI- immersion to the umbilicus for 15 min at 13-14 ºC.CONT- 15 min seated at 20-22 ºC.	Repetition of fatiguing exercise and RPE.	Repetition of fatiguing exercise (1 hr post) and RPE (upon completion of fatiguing exercises).	Peak power and total work were reduced after CWI vs CONT. RPE was not different between recoveries.
Delextrat at al. (2012)	16 (8 male, 8 female) basketball players from top ranking teams in the University Premier League, average age 23 years.	In-season basketball match.	CWI- immersion to the iliac crest for five 2 min immersions at 11 ºC, separated by 2 min rest in ambient air at 20 ºC. CONT- 30 min seated at 20 ºC.	CMJ, RSA, overall fatigue and leg soreness.	CMJ and RSA (24 hr after recovery strategy) and overall fatigue and leg soreness (immediately and 24 hr after recovery strategy).	Jump performance in males 24 hr post was greater after CWI vs CONT (p = 0.04, CL^ = -0.96 to 3.12). No effect of recovery was identified for sprint total time (p = 0.87), ideal time (p = 0.60) and decrement (p = 0.07). Perception of fatigue was lower immediately after CWI vs CONT (CL^ = -1.30 to -0.16). Leg soreness was lower immediately after CWI vs CONT (ES = -3.26 to -2.12). No other significant differences were noted.
Dunne et al. (2013)	9 male well-trained participants, average age 30 years.	Exhaustive run- run for 5min at 50% V̇max (maximum velocity) followed by 5 min at 60% V̇max and then running at 90% Vmax until failure.	CWI- immersion to the iliac crest for 15 min at 8 ºC. CWI- immersion to the iliac crest for 15 min at 15 ºC. CONT- 15 min seated at 18 ºC.	Repetition of fatiguing exercise (fatiguing exercise 2).	Fatiguing exercise 2 (25 min post).	Time to failure during fatiguing exercise 2 was longer in CWI (15 min at 8 ºC) than CONT (ES = 0.74), but not different between CWI (15 min at 15 ºC) and CONT (p = 0.06, ES = 0.68), and between the 2 CWI protocols (p = 0.4, ES = 0.21). Percentage change in time to failure from exercise 1 to exercise 2 was significantly lower after CONT vs CWI (15 min at 8 ºC) (ES = >0.8) and not different to CWI (15 min at 15 ºC) (p = 0.061, ES = 0.5-0.79). No other significant differences.
Elias et al. (2012)	14 male professional Australian footballers, average age 21 years.	1 hr mid-week pre-season training session.	CWI- immersion to the xiphoid process for 14 min at 12 ºC. CWT- immersion to the xiphoid process, 7 cycles of 1 min in 12 ºC and 1 min in 38 ºC. CONT- 14 min seated.	RSA, CMJ, SJ, perceived soreness and fatigue.	RSA, jump performance, (24 and 48 hr post), MS and fatigue (1, 24 and 48 hr post).	ES = 1.2-2 for change in mean total sprint time after CONT vs CWI and CWT at 24 hr (with CONT times slower) and ES = 0.2-0.6 at 24 and 48 hr between CWI and CWT (with CWT times slower). No ES were presented for SJ and CMJ. ES = 1.2-2 for change in mean MS and perceived fatigue after CONT in vs CWI and CWT at 1 hr (with CONT having increased scores). At 24 hr ES >2 for change in mean MS between CONT and CWI and CWT (with CONT having increased scores). At 24 hr ES = 0.6-1.2 between CWI and

						CWT for MS (with CWT having larger scores) and for perceived fatigue between CONT and CWI and CWT (with CONT having larger scores). At 48 hr post an ES >2 between CWI and CONT for change in MS (with CONT scores larger). An ES of 1.2-2 between CWT and CONT for MS and CWI and CONT for perceived fatigue (with CONT scores larger). At 48 hr an ES of 0.6-1.2 between CWI and CWT for MS (with CWT scores larger) and for perceived fatigue between CWT and CONT (CONT scores larger) and between CWI and CWT (with CWT scores larger). No other ES calculations were given.
Elias et al (2013)	24 male professional Australian footballers, average age 20 years.	75 min practice match.	CWI- immersion to the xiphoid process for 14 min at 12 ºC. CWT- immersion to the xiphoid process, 7 cycles of 1 min in 12 ºC and 1 min in 38 ºC. CONT- 14 min seated.	RSA, CMJ ratio F:C and FT, SJ F:C and FT, MS and fatigue.	RSA, jump performance, (24 and 48 hr post), MS and fatigue (percentage change difference of all variables; 1, 24 and 48 hr post).	At 24 hr for CMJ F:C CWI vs CONT ES = 0.78, CI* = 0.88; CWT vs CONT ES = 0.6, CI* of 0.73 (CONT smaller) and an unclear difference was noted CWI vs CWT. An unclear difference between interventions at 48 hr for CMJ and SJ F:C. At 24 hr post for SJ F:C CWI vs CONT ES = 1.22 CI* = 0.77 and for CMJ FT ES = 0.52, CI* = 0.46 (CONT values smaller), the other calculations for SJ F:C and CMJ FT were unclear. At 24 hr post for SJ FT CWI vs CONT ES = 1.44, CI* = 0.79; CWT vs CONT ES = 1.09, CI* = 0.74 (CONT smaller); CWI vs CWT ES = 0.56, CI* = 0.55 (CWT smaller). At 48 hr post for SJ FT CWI vs CONT ES = 0.79, CI* = 0.55; CWT vs CONT ES = 0.84, CI* = 0.61 (CONT smaller). CWI vs CWT was unclear. At 48 hr post an unclear difference for CMJ FT between all recoveries. At 24 hr post for RSA CWI vs CONT ES = -1.53. CI* = 0.53; CWT vs CONT ES = -1.08, CI* = 0.62 (CONT larger); CWI vs CWT ES = -0.56, CI* = 0.23 (CWT larger). At 48 hr post for RSA CWI vs CONT ES = -0.81, CI* = 0.62; CWT vs CONT ES = -0.51 (CONT

						larger), CI* = 0.63; CWI vs CWT ES = -0.35, CI* = 0.26 (CWT larger). At 1 hr post change in mean MS and perceived fatigue CWI vs CONT ES = -3.06, CI* = 1.49, ES = -1.59, CI* = 1.52 respectively (CONT larger), CWT vs CONT an unclear ES was calculated and CWI vs CWT ES = -2.53, CI* = 1.84, ES = -0.57, CI* = 0.63 respectively (CWT larger). At 24 hr post change in mean MS CWI vs CONT ES = -4.0, CI* = 0.69; CWT vs CONT ES = -1.68, CI* = 1.54 (CONT larger); CWI vs CWT ES = -2.51, CI* = 1.02 (CWT larger). At 24 hr post change in perceived fatigue CWI vs CONT ES = -2.7, CI* = 1.2; CWT vs CONT ES = -1.13, CI* = 0.86 (CONT larger); CWI vs CWT ES = -1.24, CI* = 1.12 (CWT larger). At 48 hr post change in mean MS CWI vs CONT ES = -3.87, CI* = 1.09; CWT vs CONT ES = -2.12, CI* = 1.13 (CONT larger); CWI vs CWT ES = -1.92, CI* = 0.27 (CWT larger). At 48 hr post change in perceived fatigue CWI vs CONT ES = -1.14, CI* = 1.06; CWT vs CONT ES = -0.43, CI* = 0.58 (CONT larger); CWI vs CWT ES = -0.57, CI* = 0.59 (CWT larger).
Fonseca et al. (2016)	8 male jiu-jitsu competitors, average age 24 years.	40 min each of calisthenics, technical training and combat simulation.	CWI- immersion of the whole body for 4 min at 6 ºC, with 1 min passive rest, repeated 3 times. CONT- passive rest.	Upper limb power, CMJ, MS and subjective perceived recovery.	All measures (immediately post, 24 and 48 hr post recovery).	At 24 hr upper limb power and CMJ was improved after CWI in comparison to CONT (p = 0.001), no other performance or perceptual differences were indicated.
French et al. (2008)	26 male volunteers, average age 24 years.	Resistance exercise challenge.	CWT- 50 cm immersion depth, 4 cycles of 1 min in 8-10 ºC alternated with 3 minutes in 37-40 ºC. CONT- passive rest.	CMJ, repeat CMJ, sprint speed, agility, whole body strength, MS or pain.	CMJ, repeat CMJ, sprint speed, agility, whole body strength (48 hr post), MS or pain (1, 24 and 48 hr post).	No differences were noted between recoveries for performance or perceptual recovery.

Garcia et al. (2016)	8 male amateur rugby union players, average age 23 years.	40 min rugby specific exercise protocol.	CWI- immersion to the iliac crest for 9 min in 9 ºC followed by 1 min at room temperature, performed twice. CONT- 20 min seated.	CMJ, 30 sec continuous jumps, agility and TQR.	All measures (20 min post recovery and 12 hr post fatiguing exercise).	At 12 hr no difference was found between interventions for agility (p = 0.15). CWI decreased agility performance (p = 0.03, ES 1.73), CMJ height and 30 sec continuous jumps in comparison to CONT 20 min post. CWI improved 30 sec continuous jump mean height and TQR in comparison to CONT at 12 hr post (30 sec continuous jump height p = 0.026, ES = 0.70; TQR p = 0.03, ES = 1.76). No other differences were indicated.
Getto et al. (2013)	23 (13 male and 10 female) division I collegiate team sport athletes	Conditioning session.	CWI- immersion to the chest for 10 min at 10 ºC. CONT- passive rest at 21 ºC.	20 m sprint, VJ and perceived soreness.	20 m sprint, VJ, (24 hr post recovery) and perceived soreness (immediately and 24 hr post recovery).	There was no difference between groups for VJ height (p = 0.89, ES = 0.01) or for group and time interaction (p = 0.75, ES = 0.06). For sprint performance there was no interaction difference between group and time (p = 0.36, ES = 0.07) and no difference between groups (p = 0.17, ES = 0.16). For perceived soreness there was no significant interaction between group and time (p = 0.18, ES = 0.11) or between groups (p = 0.81, ES = 0.02). No other differences were identified.
Jakeman et al. (2009)	18 female active participants, average age 20 years.	10 sets of 10 CMJ.	CWI- immersion to the SIS for 10 min at 10 ºC. CONT- passive rest.	Concentric muscle strength and perceived soreness.	All measures (1, 24, 48, 72 and 96 hr post).	No significant difference between groups or group by time interaction were calculated.
Juliff et al. (2014)	10 female Australian Institute of Sport netball players, average age 20 years.	15 min simulated netball circuit.	CWT- full body immersion, 7 cycles of 1 min in 15 ºC and 1 min in 38 ºC. CWT- 7 cycles of 1 min in 18ºC and 1 min in 38 ºC shower. CONT- 14 min seated at 20 ºC.	Repeated agility, whole body fatigue, recovery effectiveness perceptions.	Repeated agility (35 min, 7 and 24 hr post), whole body fatigue (35 min, 5 and 24 hr post), and recovery effectiveness perceptions (post intervention).	Main effect for recovery for fatigue was found with CWT having decreased fatigue in comparison to CONT. No other significant differences were noted.
King and Duffield (2009)	10 female trained netball players, average age 20 years.	Simulated netball exercise circuit- 4 x 15 min intermittent-sprint exercise circuit with 3 min rest at quarter	CWI- immersion to the iliac crest for 5 min in 9 ºC followed by 2.5 min seated at room temperature, performed twice. CWT- immersion of the iliac crest for 1 min in 9 ºC,	Repetition of fatiguing exercise (fatiguing exercise 2), 5 x CMJ in 20 sec,	Fatiguing exercise 2 (24 hr post), CMJ and sprints (pre and post fatiguing exercise 2), MS and RPE (after recovery, after warm	No difference was indicated between conditions for fatiguing exercise 2. At pre fatiguing exercise 2 percent decrement in CMJ CWI vs CONT ES = 0.75 (CONT larger). Post fatiguing exercise 2 percent decrement in CMJ CWT vs CONT ES = >0.7 (CONT larger). Post fatiguing exercise 2

		times and 5 min at half time.	alternated with a 39 ºC shower for 2 min for 5 cycles. ACT- low intensity jogging (40% peak speed) for 14 min. CONT- 15 min seated at 17 ºC.	5 x 20 m sprints departing every 20 sec, MS and RPE.	up, during each rest interval in fatiguing exercise 2 and after fatiguing exercise 2).	percent decrement in 20 m sprint performance CWT vs CONT ES = 0.74 (CONT larger). 24 hr post for MS CWT vs CONT ES = 0.88; CWI vs CONT ES = 0.84 (CONT larger). Post recovery strategy MS CWI and CWT vs ACT and CONT ($p < 0.05$). After recovery RPE was elevated after ACT in comparison to CWI, CWT and CONT. No other significant differences were calculated.
McCarthy et al. (2016)	15 male active participants, average age 21 years.	15 min moderate-intensity cycling followed by high-intensity cycling to exhaustion.	CWI- whole body immersion for 5 min at 8 ºC. CWI- whole body immersion for 10 min at 8 ºC. CONT- seated at 19 ºC.	Repetition of fatiguing exercise and RPE.	Repetition of fatiguing exercise (15 min post) and RPE during fatiguing exercise 2.	Time to failure, total work and number of high-intensity bouts was significantly longer during the repetition of fatiguing exercise after both CWI strategies (ES = 0.5-0.79) vs CONT. RPE during the exercise was also at times significantly greater in CONT than in both CWI strategies. No other significant differences.
Parouty et al (2010)	10 (5 male and 5 female) swimmers, average age 19 years.	100 m max freestyle swim.	CWI- whole body immersion for 5 min at 14-15 ºC. CONT- 5 min seated at 28 ºC.	Repetition of fatiguing exercise (fatiguing exercise 2), rating of perceived recovery and RPE.	Repetition of fatiguing exercise (30 min post), rating of perceived recovery (pre fatiguing exercise 2) and RPE (post fatiguing exercise 2).	Change in swim time from fatiguing exercise 1 to 2 ES = 0.2-0.5, CI* = 0.2, 3.5 (CWI slower). Fatiguing exercise 2 time ES = 0.34, CI* = 0.04, 0.63 (CWI slower). Rating of perceived recovery ES = 1, CI* = -1, 2 (CWI higher). RPE ES = 0, CI* = -1, 1.
Pointon and Duffield (2012)	10 male club-level team sport athletes, average age 21 years.	High intensity intermittent-sprint exercise protocol with and without tackling for 2 x 30 min halves with 10 min passive rest between.	CWI- immersion to the iliac crest for 9 min at 9 ºC followed by 1 min seated at room temperature, repeated twice. CONT- 20 min seated at 20 ºC.	Neuromuscular function and MS.	Neuromuscular function (immediately, 2 and 24 hr after recovery) and MS throughout the recovery, immediately, 2 and 24 hr after recovery).	Immediately after recovery CWI increased MVC, VA, RMS of VM/VL, RR, 1/2 RT, CD, duration and latency of M wave in VM in comparison to CONT (respectively p = 0.03, p = 0.05, p = 0.04, $p < 0.05$ for RR, ½ RT, CD, p = 0.02 respectively). CWI decreased MS 2 hr after recovery in comparison to CONT (p = 0.04). No other significant differences.
Pournot et al. (2011).	41 male highly-trained participants, average age 22 years.	30 min exhaustive, intermittent exercise protocol.	CWI- immersion to the iliac crest for 15 min in 10 ºC. CWT- immersion to the iliac crest, 5 cycles of 1 min 30 sec in 10 ºC and 1 min 30 sec in 42 ºC.	MVC, CMJ, mean power during a 30 sec all out rowing test and DOMS.	MVC, CMJ, mean power during a 30 sec all out rowing test (1 and 24 hr post) and DOMS (24 hr post).	No significant differences were identified.

			CONT- 15 min seated.			
Rowsell et al. (2014)	7 male triathletes, average age 29 years.	7 x 5 min running intervals at 105% of the athletes' previously determined anaerobic threshold running velocity, with a 90 sec cycle at 1.5 W/kg during intervals.	CWI- immersion to the iliac crest for 1 min in 10 ºC with 1 min out of the bath, repeated 5 times. CONT- immersion to the iliac crest for 1 min in 34 ºC with 1 min out of the bath, repeated 5 times.	Cycling measures, perception of physical and mental recovery, leg soreness, general fatigue, perceived recovery effectiveness and RPE.	Cycling measures (9 hr after recovery), perception of physical and mental recovery, leg soreness, general fatigue and perceived recovery effectiveness (pre cycling measures) and RPE (completion of the first 5 min and second 5 min of warm up, the 5-min performance test and after each 5-min interval of self-paced cycling).	No difference for time trial mean power output (CI* = 1.7%), training set mean power output (CI* = 1.7%), RPE (ES = -0.36, *p* = 0.19, CI* = 1.9%). Physical recovery (ES = 0.58, *p* = 0.017), mental (ES = 0.13, *p* = 0.85) (CWI larger), soreness (ES = -0.77, *p* = 0.08) and fatigue (ES = -0.85, *p* = 0.85; CWI larger). All subjects believed CWI to be more effective and preferable over CONT.
Schniepp et al. (2002)	10 cyclists, average age 30 years.	Maximum cycling effort over 0.2 miles.	CWI- immersion to the iliac crest for 15 min in 12 ºC. CONT- 15 min passive rest.	Repetition of fatiguing exercise.	Repetition of fatiguing exercise (15 min post).	Maximum power, average power decreased significantly more after CWI in comparison to CONT. No other significant differences.
Selwood et al. (2007)	40 (11 male and 29 female) untrained volunteers, average age 21 years.	Non-dominant leg eccentric loading protocol.	CWI- immersion to the ASIS for 1 min in 5 ºC with 1 min out of the bath, repeated 3 times. CONT- immersion to the ASIS for 1 min 24 ºC with 1 min out of the bath, repeated 3 times.	One-legged hop for distance test, maximal isometric strength and pain.	All measures (24, 48 and 72 hr post).	Change in one-legged hop distance was not different between conditions at 24 hr (*p* = 0.63), 48 hr (*p* = 0.33) and 72 hr post (*p* = 0.18). Change in maximal isometric strength was not different between conditions at 24 hr (*p* = 0.40), 48 hr (*p* = 0.88) and 72 hr (*p* = 0.79). Sit to stand pain was higher after CWI at 24 and 48 hr post (*p* = 0.009 and *p* = 0.05 respectively) and not different at 72 hr post (*p* = 0.12). Passive stretch pain was higher after CWI at 24 and 48 hr post (*p* = 0.010 and *p* = 0.041 respectively) and not different at 72 hr post (*p* = 0.093). Hopping pain was not different between recoveries at 24, 48 and 72 hr post (*p* = 0.19, *p* = 0.093 and *p* = 0.22 respectively). Running pain was higher after CWI at 24 hr (*p* = 0.038), but not different at 48 and 72 hr post (*p* = 0.088 and *p* = 0.32 respectively). Isometric contraction pain was not different between recoveries (24 hr *p* = 0.068, 48

						hr p = 0.054 and 72 hr p = 0.091). Tenderness mid-belly pain was not different between recoveries (24 hr p = 0.34, 48 hr p = 0.20 and 72 hr p = 0.12). Tenderness musculotendinous was not different between recoveries (24 hr p = 0.061, 48 hr p = 0.67 and 72 hr p = 0.31).
Stacey et al. (2010)	9 male habitually active participantss, average age 29 years.	50 kJ cycling bout time trial.	CWI- whole body immersion 10 min in 10 ºC. ACT- cycling at 50 W for 10 min. CONT- 10 min lying supine on a bed.	Repetition of fatiguing exercise x 2 (fatiguing exercise 2 and 3), quadriceps muscle pain, lower extremity energy, pain and better feelings and RPE.	Fatiguing exercise 2 and 3 (20 and 40 min post), quadriceps muscle pain (prior to fatiguing exercise 2 and 3), subjective impressions of recovery (1 hr after fatiguing exercise 3) and RPE (immediately after fatiguing exercise bout 2 and 3).	Lower extremities felt better after CWI in comparison to CONT and ACT (main recovery effect). No other differences were identified.
Stanley et al. (2012)	18 male endurance trained cyclists, average age 27 years.	60 min high intensity cycling session.	CWI- full body immersion for 5 min in 14 ºC. CWT- full body immersion 3 cycles of 1 min in 14 ºC and 2 min in 36 ºC. CONT- 10 min seated at 22 ºC.	15 min work based performance time trial and perceptions of recovery.	Performance time trial (3 hr 25 min post), perceptions of recovery (based on the average for the period from the recovery intervention to the performance trial; 45 min, 1 hr 10 min, 1 hr 40 min, 2 hr 10 min post).	No difference between CWI and CONT for performance time (ES = 0.05; CL* = -1.3 - 2.2) and mean power output (%PPO) (ES = 0.07; CL* = -1.0 - 2.1) and between CWT and CONT for time (ES = -0.12; CL* = -3.1 - 1.3). %PPO CWT vs CONT (ES = 0.31; CL* = -0.1 - 4.8; CWT larger). CWI and CWT for time (ES = -0.17; CL* = -0.5 - 3.3, no difference) and %PPO (ES = -0.24; CL* = -3.8 - 0.4; CWT larger). General fatigue for CWI and CONT (ES = -0.7; CL* = -18 - -5; CONT larger) CWT and CONT (ES = -0.7; CL* = -19 - -2; CONT larger), CWI and CWT (ES = -0.0; CL* = -11 – 11, no difference). For leg soreness CWI and CONT (ES = -1.6; CL* = -30 - -14, no difference) CONT and CWT (ES = -2.0; CL* = -37 - -15; CONT larger). No difference between CWI and CWT leg soreness (ES = 0.3; CL* = -9 - 22), for mental recovery CWI and CONT (ES = -0.0; CL* = -8 - 8). CWT vs CONT for mental recovery (ES = 0.2; CL* =-5 – 13; CWT larger), CWI and CWT (ES

						= -0.2; CL* = -14 – 8; CWT larger). No differences for physical recovery CWI and CONT (ES = 0.3; CL* = -1 - 12), CWT and CONT (ES = 0.4; CL* = -1 - 16) and CWI and CWT (ES = -0.1; CL* = -9 - 5).
Stanley et al. (2014)	14 male endurance trained cyclists, average age 25 years.	18 min of high intensity cycling interval training.	CWI- immersion to the umbilicus for 5 min at 10 ºC. CONT- 5 min standing at 27 ºC	Repetition of fatiguing exercise (fatiguing exercise 2) and RPE.	Repetition of fatiguing exercise (30 min post) and RPE (after fatiguing exercise 2).	No differences were noted.
Takeda et al. (2014)	20 male collegiate rugby players, average age 20 years.	80 min of rugby game simulation training.	CWI- full body immersion for 10 min in 15 ºC. CONT-10 min seated.	50 m sprint, vertical jump, reaction time, side steps for 20 sec, maximal anaerobic cycling power for 10 sec and feelings of fatigue.	All performance measures (24 hr post) and feelings of fatigue (within 30 sec of completion of recovery and 24 hr post fatiguing exercise).	Feelings of fatigue lower immediately after CWI in comparison to CONT. No other significant differences were presented.
Vaile et al. (2007)	13 (4 male, 9 female) recreational participants, average age 26 years.	Leg press; 5 sets of 10 eccentric contractions of 140% of 1RM with 3 min break between each set.	CWT- immersion to the ASIS, 5 cycles of 1 min in 8-10 ºC and 2 min in 40-42 ºC. CONT- 15 min seated.	Isometric squat force, SJ peak power and MS.	All measures (immediately, 24, 48, and 72 hr post recovery).	CWT showed less change in peak isometric force and SJ peak power at 24 and 48 hr in comparison to CONT. SJ peak power was reduced after CONT in comparison to CWT but with no significant difference (ES = 0.76). No other differences were noted.
White et al. (2014)	8 male recreationally active participants, average age 24 years.	1 maximal 120 m sprint every 3 min for 12 repetitions.	CWI- immersion to the iliac crest for 10 min at 10 ºC. CWI- immersion to the iliac crest for 30 min at 10 ºC. CWI- immersion to the iliac crest for 10 min at 20 ºC. CWI- immersion to the iliac crest for 30 min at 20 ºC. CONT- 45 min seated.	DJ, SJ height, ratings of perceived soreness and perceived impairment.	All measures (1, 2, 24 and 48 hr post).	At 48 hr post DJ was significantly greater after CWI (10 min at 10 ºC) in comparison to CONT. For change in SJ height at 1, 2, 24 and 48 hr post a CL* of 3.6%, 3.2%, 2.4% and 3.7% respectively for CONT in comparison to all other conditions (CONT smaller). For change in mean drop jump height at 1, 2, 24 and 48 hr post a CL* of 4.6%, 4.4%, 8.9% and 4.6% for CONT in comparison to all other conditions (CONT smallest, except at 24 hr in comparison to 30 min at 10 ºC; and at 48 hr post in comparison to 10 min at 10 ºC). No other differences were presented.

Yeung et al. (2016).	20 (10 male and 10 female) volunteers, average age 22 years.	Maximal dynamic knee extension and flexion contractions.	CWI- immersion to the iliac crest for 10 min at 12-15 ºC. CONT- 10 min passive rest at 25ºC.	Repetition of fatiguing exercise and MS.	Repetition of fatiguing exercise (10 min post) and MS (after fatiguing exercise 1, prior to and after fatiguing exercise 2 and next day.	No significant interaction effect between recoveries was for peak torque (p = 0.96), work (p = 0.68) and fatigue rate (p = 0.98). CWI improved MS 1 day post (ES = 0.44 and $p < 0.05$). No other significant differences were calculated.

Note. CWI = cold water immersion; CWT = contrast water therapy; ACT = active recovery; CONT = control; ES = effect size; CI = confidence interval; CL= confidence limit; MVC = maximum voluntary contraction; 40CMJ = 40kg weighted countermovement jump; SJ = squat jump; MS = muscle soreness; DOMS = delayed onset muscle soreness; VJ = vertical jump; $\dot{V}O_2$ = volume of oxygen; TQR = total quality recovery scale; ASIS = anterior superior iliac spine; RPErec = Rating of perceived exertion recovery; RPE = rating of perceived exertion; RSA = repeated sprint ability; $\dot{V}$max = maximum velocity; F:C = flight time to contraction time; FT = flight time; VA = voluntary activation; RMS = root mean square; VM/VL = vastus medialis/vastus lateralis; RR = slowed rate of relaxation; 1/2RT = half relaxation time; CD = contraction duration; DJ = drop jump

2.4.3 Characteristics of the fatigue inducing protocols. A variety of fatigue inducing exercises were undertaken in the 37 studies analysed, with no studies utilising the same exercise protocol, except 2 studies that used the Loughborough intermittent shuttle run test (Bailey al., 2007; Corbett et al., 2012; Table 2.3). Exercise ranged in duration from a 30 sec max cycling test (Crowe et al., 2007; Schniepp et al., 2002) to a university premier league basketball match which may take up to 2 hr (Delextrat et al., 2012). A variation of exercises were undertaken such as; high-intensity anaerobic dominant exercise interspersed with breaks and without, games, training sessions, cycling, simulated games or game halves to induce fatigue, incremental exercise to exhaustion tests and resistance exercise (Table 2.3).

2.4.4 Characteristics of the control condition. As per the inclusion criteria all 37 studies used a CONT protocol. Most studies utilised a seated position (not in a bath; 57%). Control duration ranged from 5-45 min, with 15 min the most used duration (27%; Table 2.3). Control temperature ranged from 17-35 ºC (water and air temperatures), with 35% of studies not stating the temperature, the most used temperature was 21 ºC (14%). The CONT protocol utilised by Stacey and colleagues (2010) was implemented three times throughout the testing day, after each bout of fatiguing exercise, in comparison to all other studies that only implemented CONT after the single bout of fatiguing exercise.

2.4.5 Characteristics of cold water immersion. Thirty-nine different CWI protocols were utilised across 32 studies, with five studies utilising more than one CWI protocol (Brophy-Williams et al., 2011; Corbett et al., 2012; Dunne et al., 2013; McCarthy et al., 2016; White et al., 2014). Immersion depth ranged from the hip to the whole body (excluding head and neck), with most protocols using immersion to the hip (51%). Immersion duration ranged from 2-30 min, with the most common duration of 10 min (36%; Table 2.3). Seven studies utilised bouts of CWI interspersed with time at environmental temperatures. Immersion temperature ranged from 5-20 ºC, with 10 ºC the most frequently used (31%).

Brophy-Williams and colleagues (2011) utilised two CWI protocols with one performed immediately after the high intensity interval session and one performed 3 hr after the interval session. The CWI protocol utilised by Stacey and colleagues (2010) was implemented three times throughout the testing day, after each fatiguing exercise, in comparison to all other studies that only implemented CWI after the single bout of fatiguing exercise. Implementation time post fatiguing exercise ranged from immediately to 3 hr post, with most implementations taking place immediately and 5 min post fatiguing exercise (21% each).

2.4.6 Characteristics of contrast water therapy. Fourteen different CWT protocols were utilised across 12 studies, with two studies utilising two CWT protocols (Crampton et al., 2011; Juliff et al., 2014). The number of cycles ranged from three to seven, with seven and five cycles most frequently used (29% each; Table 2.3). Immersion depth for both the cold and hot water components ranged from hip height to shower immersion. The most used CWI water immersion depth was hip height (50%). Hot water immersion (HWI) depth was the same for the CWI depth except in King and Duffield (2009) where a shower was used for HWI. Cold water immersion component duration ranged from 1-2.5 min per immersion with 1 min per immersion most used (79%; Table 2.3). The hot water immersion component duration ranged from 1-4 min per immersion, with the most used duration of 1 min per immersion (36%). The CWI component temperature ranged from 8-18 ºC, with 10 ºC and 8 ºC the most used temperature (21% each). The HWI component temperature ranged from 36-42 ºC, with 38 ºC the most used temperatures (29%; Table 2.3). Implementation time post fatiguing exercise ranged from immediately to 20 min post, with most implementations taking place at 20 min post (21%).

2.4.7 Characteristics of active recovery. Five studies utilised an ACT protocol. Duration ranged from 10-30 min. Activities included; running, walking and cycling, with the most used ACT protocol of running at 40% of peak speed (2 studies; Table 2.3). The ACT protocol utilised by Stacey and colleagues (2010) was implemented three times throughout the testing day, after each fatiguing exercise, in comparison to all other studies that only implemented ACT after a single bout of fatiguing exercise. Implementation time post fatiguing exercise ranged from immediately to within 20 min, with immediately and 5 min the most used (40% each).

2.4.8 Cold water immersion effects on performance.

2.4.8.1 Effects on anaerobic performance. Please see Appendix A; Tables A.1-A.3 for result tables. No difference was found between CWI and CONT for recovery of muscle strength variables (such as MVC and peak torque) and jump variables (such as power, velocity and height) in 84% of time points (time points ranging from immediately post to 168 hr post). No difference was found between CWI and CONT for sprint variables (such as mean and total time) in 75% of time points (time points ranging from within 30 min post to 168 hr post). Rope climb improved after CWI in comparison to CONT in 100% of time points (30 min and 24 hr post). No difference was found between CWI and CONT for all hop test, reaction time and side step performance (time points ranging from 24 hr post to 168 hr post). No difference was found between CWI and CONT for cycling test variables in 67% of time points (ranging from 15 min to 9 hr post). Power test performance did not differ after CWI in comparison to CONT in 80% of time points (ranging from immediately to 48 hr post). Agility performance was decreased after CWI in comparison to CONT immediately post recovery and no difference was indicated at 12 hr post. Maximal swim performance was decreased after CWI in comparison to CONT. No difference was indicated between CWI and CWT for muscle strength, jump, sprint and cycling test variables and a power test at all time points (ranging from 5 min to 48 hr post). No difference was indicated between CWI and ACT for MVC, jump, sprint and cycling test variables and a hop test at all time points (ranging from 20 min to 168 hr post).

2.4.8.2 Effects on endurance. See Appendix A; Table A.4 for tabular results. For endurance at 24 hr post one CWI protocol improved performance whilst a second CWI protocol indicated no difference.

2.4.8.3 Effects on time to failure/exhaustion. See Appendix A; Tables A.5-A.7 for tabular results. Run to exhaustion results at 25 min post were no different after one CWI protocol in comparison to CONT and were improved after a different CWI protocol in comparison to CONT. Cycling to exhaustion improved after CWI in comparison to CONT in all studies at 15 min and 40 min post. Cold water immersion improved cycling to exhaustion performance in comparison to CWT and ACT at 40 min post.

2.4.9 Cold water immersion effects on perceptions.

2.4.9.1 Effects on muscle soreness. See Appendix A; Tables A.8-A.10 for tabular data. Perceived soreness did not change after CWI in comparison to CONT in 70% of time points (ranging from during recovery to 168 hr post). No difference was indicated between CWI and CWT for soreness in 62% of cases (time points ranging from immediately to 25 hr post). No difference was indicated between CWI and ACT for soreness in 86% of circumstances (time points ranging from 24 hr to 168 hr post).

2.4.9.2 Effects on rating of perceived exertion (RPE). See Appendix A; Tables A.11-A.13 for tabular data. No difference was calculated between CWI and CONT for RPE in 89% of circumstances (times ranging from immediately to 25 hr post). No difference between CWI and CWT for RPE (times ranging from immediately to 25 hr post). No difference between CWI and ACT for RPE in 80% of cases (times ranging from immediately to 25 hr post).

2.4.9.3 Effects on other perception measures. See Appendix A; Tables A.14-A.16 for tabular data. Perceived fatigue improved 62% of the time after CWI in comparison to CONT (times ranging from immediately to 48 hr post). Pain measures did not differ after CWI in comparison to CONT 82% of the time (times ranging from immediately to 72 hr post). No difference was indicated 64% of the time (ranging from immediately to 72 hr post) between CWI and CONT for perceptual questionnaire results (such as physical and mental readiness to exercise). Cold water immersion was not rated any higher than CONT 67% of the time at the conclusion of testing. Total quality recovery was improved after CWI in comparison to CONT 80% of the time (12 hr and 24 hr post). Subjective perceived recovery ratings did not differ after CWI and CONT 90% of the time (ranging from immediately to 48 hr post). No differences were indicated between CWI and CONT for perceived impairment (time ranging from 1 hr to 48 hr post). No difference was indicated between CWI and CWT for perceived fatigue 78% of the time (ranging from 5 min to 48 hr post) and for perceptual questionnaire results at 1 hr 30 min. No difference was calculated between CWI and ACT for pain measures and subjective perceived recovery (time ranging from 20 min to 1 hr 40 min).

2.4.10 Contrast water therapy effects on performance.

2.4.10.1 Effects on anaerobic performance. See Appendix A; Tables A.17-A.18 for tabular data. Muscle strength, agility and power results did not differ after CWT in comparison to CONT at all time points (ranging from 5 min to 48 hr post). Jump variables (such as power, height and flight time) did not change between CWT and CONT in 79% of time points (ranging from immediately to 72 hr post). Cycling test performance did not change after CWT in comparison to CONT in 67% of circumstances (35 min and 3 hr 25 min post). Sprint variables (such as time and mean) did not differ after CWT in comparison to CONT in 63% of time points (24 hr and 48 hr post). Less change in isometric squat force was noted in 2 circumstances (24 and 48 hr post) and no differences in 2 other circumstances (immediately and 72 hr post). No differences were indicated between ACT and CWT for sprint variables and jump variables (24 and 25 hr post).

2.4.10.2 Effects on time to failure. See Appendix A; Tables A.19-A.20 for tabular data. No difference was indicated between CWT and CONT for runs to exhaustion (4 hr post). Cycling to exhaustion improved in 100% of circumstances (35 min and 40 min) after CWT in comparison to CONT. No difference was calculated between ACT and CWT for runs to exhaustion at 4 hr post. Active recovery decreased cycling to exhaustion performance in comparison to CWT at 40 min post.

2.4.11 Contrast water therapy effects on perceptions.

2.4.11.1 Effects on muscle soreness. See Appendix A; A.21-A.22 for tabular data. Soreness did not differ after CWT in comparison to CONT in 65% of circumstances (time ranging from immediately to 48 hr post) or between CWT and ACT in 67% of circumstances (24 hr and 25 hr post).

2.4.11.2 Effects on RPE. See Appendix A; Tables A.23-A.24 for tabular data. No difference were found between CWT and CONT for RPE in all circumstances (time ranging from immediately to 25 hr post) and between ACT and CWT 80% of the time (ranging from 20 min post to 25 hr post).

2.4.11.3 Effects on other perception measures. See Appendix A; Tables A.25-A.26 for tabular data. Perceived fatigue did not differ after CWT in comparison to CONT in 67% of time points (ranging from 5 min to 48 hr post). Perceived pain and RPErec did not differ after CWT in comparison to CONT (time ranging from immediately to 48 hr post). Contrast water therapy was rated higher than CONT at the conclusion of testing in one study. Perceptual questionnaire results did not differ between CWT and CONT 50% of the time and improved after CWT in comparison to CONT 50% of the time. No difference was indicated between CWT and ACT for RPErec at all time points.

2.4.12 Active recovery effects on performance.

See Appendix A; Tables A.27-A.28 for tabular data. No differences were indicated between ACT and CONT for sprint variables, jump variables, cycling test variables, MVC, hop test, runs to exhaustion and cycling to exhaustion (time ranging from 20 min to 168 hr post).

2.4.13 Active recovery effects on perceptions.

See Appendix A; Tables A.29-A.31 for tabular data. Perceived soreness, RPErec, pain measures and subjective perceived recovery did not differ between ACT and CONT at all time points (ranging from immediately to 168 hr post). No differences were indicated between ACT and CONT for RPE 80% of the time (ranging from 20 min to 25 hr post).

2.6 Discussion

The thirty-seven included studies showed diversity in participants, exercise protocols, recovery protocols and variables investigated. According to the PEDro quantitative methodological quality scoring system and the modified IVS rating, all of the articles included in this systematic review were of limited (7/37) or moderate (30/37) methodological quality, indicating the need for more high quality research. When comparing the studies with the lowest and highest methodological quality scores, there is no consistency in findings with both qualities of papers reporting some differences and no differences between variables at different time points. Interestingly, all studies compared CWI and CONT. The criteria that had the least adherence were blinding of therapists, assessors and adequate data collection. The blinding criteria due to the nature of the studies was very difficult to meet. Although, it is interesting that the data collection was not considered adequate. This criteria refers to adequate identification of which participant results the data represents whether it is all or partial.

2.5.1 Recovery effects on performance.

Mostly CWI was no better than CONT for performance; of 190 time points over the 32 studies, 77% of the time points indicated no difference between CWI and CONT. In 17% of the time points CWI improved in comparison to CONT and in 4% of the time points CWI decreased performance in comparison to CONT. Specifically improvements occurred immediately, 15 min, 25 min, 30 min, 12 hr, 24 and 48 hr post. Of special note is that the only times CWI was found to be detrimental were for anaerobic performance at 1 hr post or earlier (15 min, 20 min and 30 min post) following the completion of the recovery strategy (Crowe et al., 2007; Garcia et al., 2015; Parouty et al., 2010; Schniepp et al., 2002) it is likely these times did not allow sufficient time for the muscles to rewarm. Crowe and colleagues (2007) found CWI to be ineffective and reason that cold water may cause peripheral vasoconstriction and less blood flow to major muscle groups, which combined with insufficient time for muscles to rewarm, could have attributed to the decreased anaerobic performance at these times. A number of studies utilised more than one CWI protocol (Brophy-Williams et al., 2011; Corbett et al., 2012; Dunne et al., 2013; McCarthy et al., 2016; White et al., 2014) with no difference between CWI protocols noted, giving no clear indication in terms of a superior CWI method. Although positive effects from CWI have been noted, most of the time points from the 32 studies indicated CWI to be no better than CONT for performance. A major contributor to this finding may have been that the fatiguing exercise in almost one third (10 of 32) of the studies was not effective in inducing performance detriments at the times of variable testing.

When comparing the protocols that were effective at inducing positive results and those that were not, no specific protocol differences can be noted. Cold water immersion may have been effective for post-exercise recovery in particular studies due to the hydrostatic pressure placed on the body that facilitates venous return (Kaczmarek et al., 2013), increased cardiac output and reduced peripheral resistance (Wilcock et al., 2006). A reduction in neuron transmission speed within the body may have also decreased experienced pain (Meeusen & Lievens, 1986), and may have alleviated some sensations associated with tiredness and allowed the athlete to perform better. Cold water immersion has also been found to be beneficial to subsequent running performance by decreasing heart rate and core temperature (Dunne et al., 2013). Cold water immersion may also provide a means to restore homeostasis and reduce intramuscular temperature (Myrer, Measom, & Fellingham, 1998), redirect blood flow (Machado et al., 2015), increase central blood volume, improve venous return and cardiac efficiency (Dunne et al., 2013), all these factors contributing to enhanced recovery.

Overall, out of the 59 time points from the 12 studies CWT improved performance at 24% of the time points, with no decreases in performance. Specifically CWT improved anaerobic performance in comparison to CONT at 35 min, 24 hr, 25 hr and 48 hr post and cycling time to failure at 35 min post. A number of studies utilised more than one CWT method, with all studies showing no difference between CWT protocols (Crampton et al., 2011; Juliff et al., 2014). A number of studies found no difference between CWT and CONT for performance. One reason may be the utilised CONT protocols. For example Juliff and colleagues (2014) implemented a CONT protocol where participants were seated for 14 min at 20 ºC which was only 2 ºC hotter than the CWI component of the CWT shower protocol implemented; this may have led to the no differences found between the two protocols for performance. For the times that CWT was effective this may be due to four reasons (although untested); firstly, the induced hydrostatic pressure causing muscular and vascular compression and less swelling. Secondly, the hot component of CWT may increase vasodilation which increases the supply of oxygen to the muscles (Vaile et al., 2007). Thirdly, the CWI component of CWT decreases skin temperature which causes an increase in sympathetic drive causing a shift in blood from the limbs (Vaile et al., 2007). Lastly, the transitions from CWI (vasoconstriction) to hot water (vasodilation) which may lead to attenuation of the immune response and decreased muscle damage (Vaile et al., 2007). Cold water immersion was found to be superior to CWT at 40 min post for cycling time to failure; it is not known why CWT was less effective at this time point.

At all 17 time points where ACT was utilised, ACT was found to be no better or worse than CONT. The ACT recovery did however decrease cycling to exhaustion at 40 min post in comparison to CWI and CWT (Crampton et al., 2013). The ACT protocols that were found to have no effect upon 50 kJ cycling time trial (20 and 40 min post; Stacey et al., 2010), anaerobic variables (24 hr, 48 hr, 72 hr and 168 hr post; Corbett et al., 2012), intermittent sprint exercise, CMJ and sprint performance (4 hr post; Coffey et al., 2004) and cycling to exhaustion (24 hr post; King & Duffield, 2009), were a shorter duration of 10-14 min. Whereas the cycling ACT protocol of double the duration was found to reduce cycling time to failure (40 min post) in comparison to CWI and CWT (Crampton et al., 2013). The 30 min ACT protocol may have been too long and induced muscle damage and fatigue which caused decreased cycle to exhaustion results (Crampton et al., 2013), with all other shorter ACT recovery strategies not producing detrimental results. Barnett (2006) in their recovery review found ACT does not improve performance and states that ACT may be ineffective at improving performance due to lack of glycogen resynthesis. It is recommended from these findings that a shorter duration ACT protocol of 10-14 min be given preference over a longer duration protocol.

2.5.2 Recovery effects on perceptions.

Of the 180 time points that perceptual measures were compared between CWI and CONT, 27% of the time CWI was found to improve perceptual measures, with no decreases. Improvement occurred immediately, 15 min, within 30 min, 1 hr, 1 hr 30 min, 2 hr, 9 hr, 12 hr, 24 hr and 48 hr post and at the conclusion of testing. When CWI recovery strategies were compared, no superior strategy was indicated. As previously stated it is unknown why CWI showed no difference in comparison to CONT most of the time, except that possibly the fatiguing exercise did not induce detrimental perceptual recovery in 9/28 studies. For the times that CWI did improve perceptual recovery it may be due to the buoyancy component of CWI which may reduce fatigue by reducing the gravitational forces on the body and in turn reduced neuromuscular activation and conservation of energy (Wilcock et al., 2006). Analgesia is associated with CWI (Jakeman et al., 2009), and may alleviate some sensations associated with tiredness. Cold water immersion may also restore homeostasis and reduce intramuscular temperature (Myrer et al., 1998) and thus enhance feelings of recovery. Cold water immersion also improved soreness recordings in comparison to CWT at 1 hr, 24 hr and 48 hr post and fatigue at 24 hr and 48 hr post (24% of perceptual recordings), it is not known why these improvements occurred in comparison to CWT.

Of the 48 time points CWT and CONT were compared for perceptual recovery, CWT improved perceptions of recovery 27% of the time, with no decreases. With perceptions of recovery improved after CWT in comparison to CONT immediately post recovery, 1 hr, 1 hr 30 min, 24 hr, 48 hr and at the conclusion of testing. When two different CWT protocols were utilised there was found to be no difference between their effects upon perceptual recovery. As previously stated it is unknown why CWT showed no difference in comparison to CONT most of the time, except that possibly the fatiguing exercise did not induce detrimental perceptual recovery in 2/10 studies. Improved perception after CWT may be due to the buoyancy component of water immersion (Wilcock et al., 2006). It may also be due to the inclusion of heat. Hot water has been found to have a relaxing, therapeutic effect upon the body (Kovacs & Baker, 2014) and stimulates thermoreceptors which send a signal faster to the brain than the pain receptors (Lee et al., 2013), potentially reducing perceived pain due to the gate control theory (Lane & Latham, 2009). Contrast water therapy was found to increase soreness in comparison to CWI at 1 hr, 24 hr and 48 hr post and fatigue at 24 hr and 48 hr post (24% of perceptual recordings), it is not known why these negative differences occurred.

Of the 22 time points that ACT and CONT were compared for perceptual recovery, in one study (King & Duffield) immediately post recovery ACT was found to increase RPE in comparison to CONT. At all other time points (immediately, shortly after recovery, 20 min, 40 min, 1 hr, 1 hr 40 min, before and immediately after fatiguing exercise 2 at 4 hr post, 24 hr, 25 hr, 48 hr, 72 hr and 168 hr post) no difference was indicated between ACT and CONT for perceptual recovery (Coffey et al., 2004; Corbett et al., 2012; King & Duffield, 2009; Stacey et al., 2010). Muscle soreness and RPE were both found to be increased immediately after ACT in comparison to CWI and CWT (King & Duffield, 2009). It is likely that ACT increases perceptions of soreness due to the extra movement undertaken in these protocols in comparison to the other static recovery strategies for the same amount of time. Also important to note is that the increase in perceptual soreness were found directly after utilising ACT, at later time points there were no changes between recovery strategies, this is most likely due to feelings of soreness dissipated by this time.

2.7 Conclusion

This systematic review included articles which were of low-moderate quality and highlights the variety of methods used to evaluate the effects of varied CWI, CWT and ACT recovery strategies; resulting in contrasting outcomes. These outcomes support findings of other reviews which state the uncertainty of the effectiveness of CWT (Cochrane, 2004; Hing et al., 2008) and CWI (Barnett, 2006; Torres et al., 2012). Based on low-moderate quality research, it is recommended that if a recovery strategy be undertaken that a CWT recovery be undertaken, as it did not induce negative performance or perceptual recovery in comparison to CONT. It is also recommended that if ACT is to be used that a shorter duration (10-14 min) protocol is implemented. High quality research is needed to verify these recommendations in a variety of game and tournament based scenarios.

This systematic review compared the relative effectiveness of water immersion, ACT and CONT recovery strategies and demonstrated the conflicting nature of recovery research. In response to these review findings, the remainder of this thesis will provide details of new research undertaken to determine the use of and effectiveness of a variety of recovery strategies.

Chapter 3

Team Sport Athletes' Understanding of Recovery Strategies

<u>This chapter has been adapted from the publication:</u>

Crowther, F., Sealey, R., Crowe, M., Edwards, A., & Halson, S. (2017). Team sport athletes' perceptions and use of recovery strategies: a mixed-methods survey study. *BMC Sports Science, Medicine and Rehabilitation, 9*(6). doi: 10.1186/s13102-017-0071-3

3.1 Abstract

A variety of recovery strategies are used by athletes, although there is currently no research that investigates perceptions and usage of recovery by different competition levels of team sport athletes.

The recovery techniques used by team sport athletes of different competition levels was investigated by survey. Specifically this study investigated if, when, why and how the following recovery strategies were used: active, land-based recovery (ALB), active, water-based recovery (AWB), STR, CWI and CWT.

Three hundred and thirty-one athletes were surveyed. Fifty-seven percent were found to utilise one or more recovery strategies. Stretching was rated the most effective recovery strategy (4.4/5) with ALB considered the least effective by its users (3.6/5). The water immersion strategies were considered effective or ineffective mainly due to psychological reasons; in contrast STR and ALB were considered to be effective or ineffective mainly due to physical reasons.

This study demonstrates that individuals do not always understand the effects a recovery strategy has upon their physical recovery and thus athlete and coach recovery

education is encouraged. This study also provides new information on the prevalence of different strategies and contextual information that may be useful to inform best practice among coaches and athletes.

3.2 Introduction

There are many post-exercise recovery options currently available for athletes; some of these include water immersion, STR, walking and/or jogging, swimming or pool walking, massage, sleeping/napping and fluid/food replacement (Halson, 2013; Hing et al., 2010; Venter et al., 2010). Although it is generally accepted that many athletes undertake these types of post-exercise recovery, to the authors' knowledge there is currently no data available on the popularity of recovery strategies used by Australian-based athletes across a range of team sports and competition levels. It is also unclear why athletes partake in recovery strategies and if they believe they are effective or ineffective.

A survey undertaken by elite South African team sport athletes reported sleep, fluid replacement and socialising with friends as the most popular recovery strategies undertaken (Venter, 2014). Stretching and CWI were found to be most used by elite South African rugby players (83%), followed by active recovery (74%), with CWI rated most effective (Van Wyk & Lambert, 2009). Seventy-nine per cent of surveyed elite New Zealand athletes reported the use of CWT (Hing et al., 2010). Interviews with coaches from a state academy of sport in Australia indicated that accessibility and practicality of recovery methods influenced their implementation of different recovery strategies, with the most popular recovery strategies being nutrition, STR, ACT and CWT (Simjanovic et al., 2009). Coaches implemented recovery strategies that they perceived as being effective based on their own past experiences, observations and instinct rather than scientific evidence (Simjanovic et al., 2009). Moreno and colleagues (2015) found that an individualistic approach to player recovery is required, after Spanish professional basketball players were found to use varying recovery strategies and have different perceptions of them.

These studies provide some insight into the most popular recovery methods used by elite team sport athletes in a limited number of countries, but do not capture recovery use by sub-elite levels of sports participation and athlete perceptions and reasons for usage of recovery. Furthermore, although Australian coaches' views on recovery have been reported (Simjanovic et al., 2009) there appears to be no investigation into the use of recovery strategies by Australian athletes. In response to the widespread use of land and water-based recovery strategies with current uncertainty regarding their effectiveness and reasons for use, this study employed a survey to investigate the popularity of recovery techniques used by team sport athletes across various levels of competition in parts of Australia. This study will also report if/when, why and how the following five recovery strategies are used: ALB, AWB, STR, CWI and CWT. This study will also compare the reported reasons for use with available scientific evidence of recovery mechanisms. It is hypothesised that the majority of athletes use recovery, with STR likely the most popular choice by all levels of athlete, due to its accessibility and that is able to be undertaken as a team. It is also hypothesised that water immersion strategies will be considered the most beneficial recovery strategies, due to the high use of these recovery strategies by elite athletes portrayed in the media.

3.3 Methods

To determine the popularity of specific recovery methods and their reasons for use a survey was deployed that consisted of questions requiring a combination of checkbox, Likert scale and open ended, free text responses. A survey was deployed as it was accessible by a large number of people from different sports. The survey design was based on a combination of previously published surveys on recovery strategies (Hing et al., 2010; Simjanovic et al., 2009; Venter et al., 2010). The survey was available for completion in print, comprised of seven sections, and took approximately 20 min to complete. In a pilot study, the questionnaire was trialled with 10 people consisting of higher degree research students and their supervisors to assess the clarity and comprehension of the questionnaire as well as an approximate completion time. From this pilot study no further revisions were made to the questionnaire and the approximate completion time of 20 min was determined.

Coaches/administrators from a convenience sample of 59 sporting teams/organisations within the northern region of Queensland, Australia were contacted via email or phone to provide consent for their team members to participate in the study. Organisation email addresses and phone numbers were obtained via internet searching or by personal contacts. Competitors from a range of team sports (Figure 3.1) across a variety of senior competition levels (excluding social competition) from five cities/towns provided individual consent and completed the survey after a game or training session over a 15 month period between September 2013 and November 2014 (Figure 3.1). Players from a Melbourne-based basketball college also participated following a snowball invitation by a coach from the survey sampling area. Ethics approval was granted by the Human Ethics Committee of James Cook University, Australia (H5248) and the rights of the participant were protected (Appendix B).

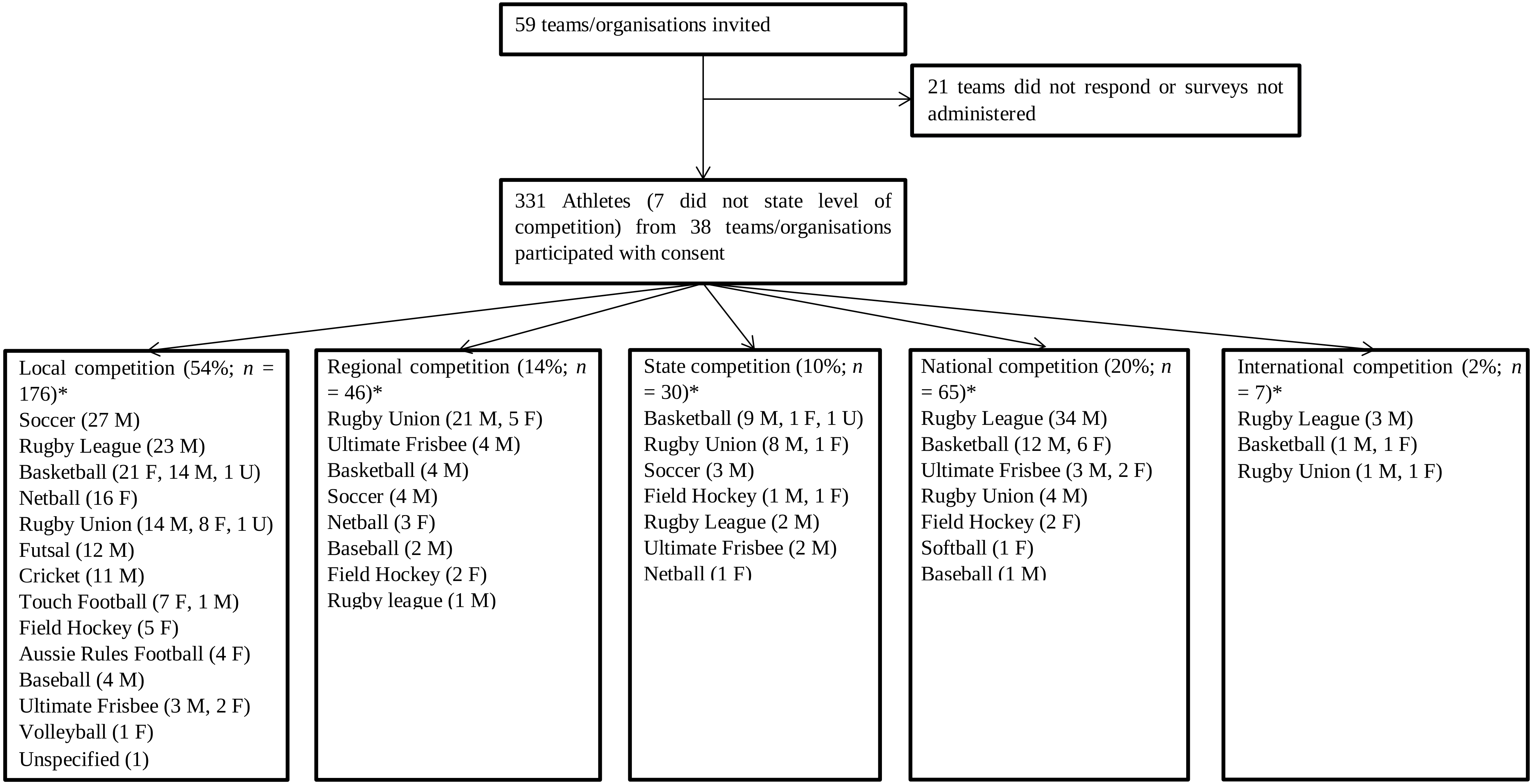

Figure 3.1. Major sport and level of competition of survey participants.

*Participants were allocated according to their highest level of current competition for their dominant sport; F = female, M = male, U = unspecified.

The first section of the survey consisted of demographic information. Participants nominated the major sport that they played and the competition months for that sport, the highest level of competition in which they currently engaged for that sport, the weekly frequency and duration of competition and training, and their age and gender. Local sport level was classified as athletes that are part of a local team, competing against other teams in the local area such as within-city competition. Regional was selected if athletes were part of a city/town-based team and competing against other city/town based teams from within the surrounding region. State level athletes may be competing for a local or regional team, in a competition against other teams from across the state. National athletes were either competing in a national competition such as the NRL or were selected to represent their state in an upcoming national event. Lastly, international athletes were selected to represent their country or were currently competing for their country. The second section investigated the recovery strategies employed by the participants. Participants were asked to answer either 'yes' or 'no' separately to whether they performed a recovery strategy after competition, and/or after pre-season training and/or after in-season training. Participants who did not partake in a recovery strategy were invited to explain in free text why they did not, and this concluded their survey participation. Conversely, if participants answered 'yes' to any of the three questions about recovery strategy use, they were then invited to select from a predetermined list, (Hing et al., 2010; Venter et al., 2010) the recovery strategies that they use after competition, pre-season and/or in-season training; and then in free text to nominate which recovery strategy they believed to be the most effective. The list of recovery strategies included; ALB, AWB, STR, CWI, CWT, massage, sleep/nap, food and/or fluid replacement, ice pack/vest application, heat pack application, liniment or gel application, progressive muscle relaxation or imagery, prayer or music, reflexology or acupuncture, supplement use, medication use and other (participants were asked to specify).

Sections 3-7 of the survey investigated the use of ALB, AWB, STR, CWI and CWT recovery strategies, with one section allocated to each recovery strategy. These strategies were selected based on published research methodologies (Hing et al., 2010; Venter et al., 2010) and the strategies commonly used by Australian sporting teams (Halson, 2013; Simjanovic et al., 2009). The following definitions of recovery strategies were included in the survey to assist respondents: ALB- includes activities such as or similar to walking, slow jogging, low intensity cycling; AWB- includes activities such as swimming, pool walking, pool jogging; STR - includes static STR, proprioceptive neuromuscular facilitation (PNF) STR, or dynamic STR (with descriptions included); CWI- includes immersion in cold or ice water; and CWT- includes alternation between immersion in cold/ice water and hot water. In each of these sections participants were asked whether they performed the recovery after competition, after pre-season training and/or after in-season training. If they answered 'yes' to any of these questions the participant was directed to answer more questions about that specific recovery strategy. If the participant answered 'no' to the three questions they were invited to move to the next section of the survey. The additional questions in each section focused on the perceived effect of each recovery strategy. Participants rated from 1 (not at all) to 5 (very) how effective they considered the recovery strategy to be and were invited to provide a description of why they thought the recovery strategy was effective or ineffective. From a list of twenty potential reasons (Hing et al., 2010; Venter et al., 2010; Table 3.1), participants rated how important they thought each reason was for performing the specific recovery strategy from 1 (not important reason) to 5 (very important reason). At the end of each section (sections 3-7) participants were invited to provide specific details about the recovery sessions they undertook (session type, description of recovery, duration and intensity of recovery and how long after the session the recovery was performed). To view the full survey please see Appendix C.

3.3.1 Statistical analyses

A combination of quantitative and qualitative analyses were conducted. The quantitative analyses was conducted on the scale-based ratings data using Statistical Package for Social Sciences (IBM SPSS Incorporation, version 22, Chicago, Ill, USA). The data were found to be approximately normally distributed with the large sample size of 205 in sections 3-7, thus repeated measures ANOVA tests with an alpha set at .05 were conducted to compare ratings across the five recovery strategies. Data were presented as *M*, (*SD*) or proportions (%) of responses. Qualitative analysis involved grouping popular responses into specific themes and quoting text directly as specific examples. The identification of themes and allocation of themes was undertaken by two researchers independently. The researchers compared their analysis and together developed the final themes and allocation of responses to themes via consensus. Responses given for reasons for perceived effectiveness of the five recovery strategies were allocated to one of five themes; physical reason, physiological reason, psychological reason, general/unspecified response and sceptical/unsure/neutral thoughts about effectiveness.

3.4 Results

Three hundred and thirty-one athletes from 38 teams (71% male, $M = 25$, $SD = 7$ years) completed the paper-based surveys. Fourteen team sports and five levels of competition were represented (Figure 3.1). Local competition was most represented (54%), followed by national (20%) regional (14%), state (10%) and international (2%). Basketball was the most represented team sport (22%) followed by rugby league and rugby union (20% each), soccer (10%) and netball (6%). Across all sports and levels of competition athletes competed in 0-7 games per week (the number zero may be due to being injured at the time of surveying or the participant was unable to compete every week), equating to 0-600 min of competition per week and trained for 0-30 or more hr per week (the number zero refers to those who do not train). One competition game, 60 min of competition and 4 hr of training per week were the most common responses for the competition and training demographics.

Fifty-nine percent of participants self-reported (selected checkbox options) performing a recovery strategy following competition, 55% after pre-season training and 57% used recovery strategies after in-season training. All participants who performed at an international level indicated using massage for recovery (Figure 3.2). In contrast the most popular recovery method undertaken by all other levels of athletes (selected checkbox options) was STR (98% national, 79% state, 87% regional and 77% local; Figure 3.2). Food/fluid (84% regional and 67% local) and ALB (74% regional and 52% local) were the next most popular recovery techniques used by both regional and local athletes (Figure 3.2). Figures 3.3-3.6 show that national athletes used ALB, AWB, CWI and CWT the most (75%, 92%, 90% and 47% respectively) and local athletes used these recovery strategies the least (52%, 36%, 23% and 22% respectively) in comparison to the other competition levels of athlete.

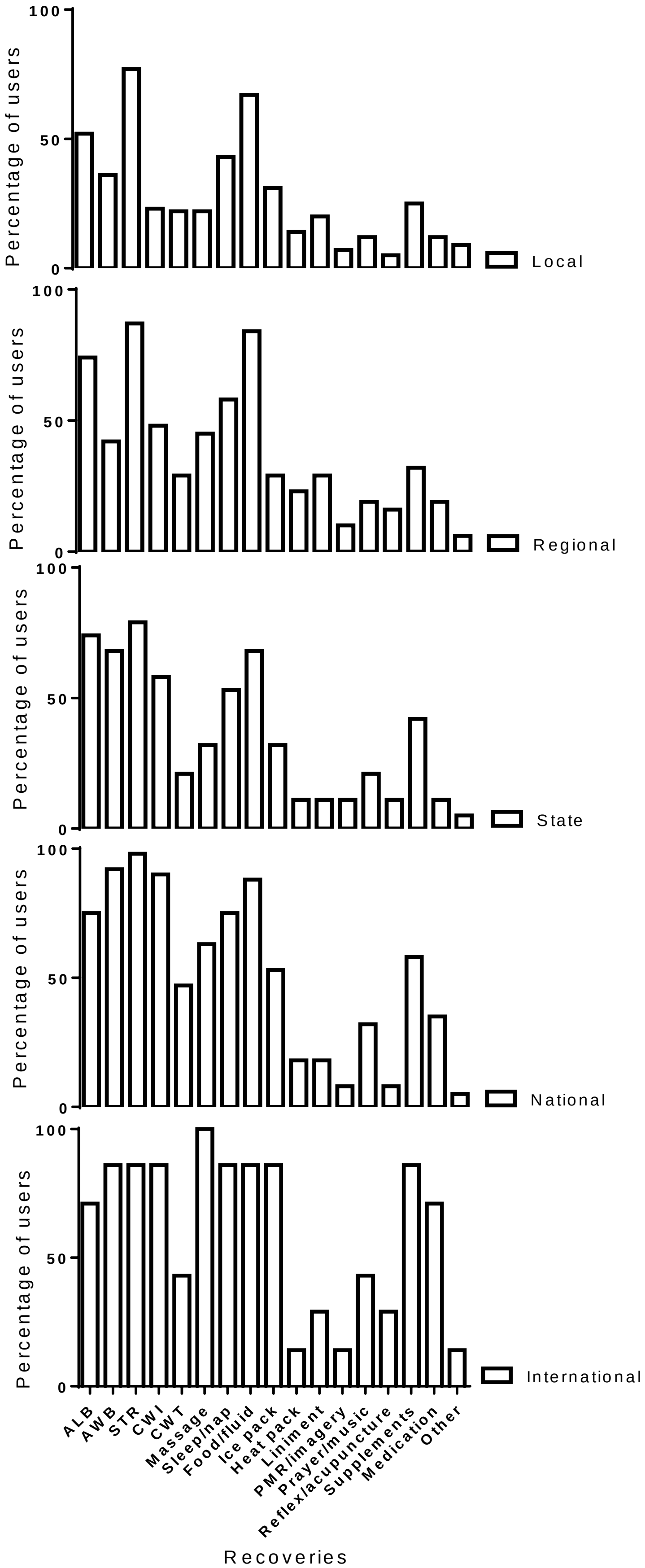

Figure 3.2. Recovery strategies undertaken by team sport athletes competing in local, regional, state, national and international competition.

PMR = progressive muscle relation; reflex = reflexology

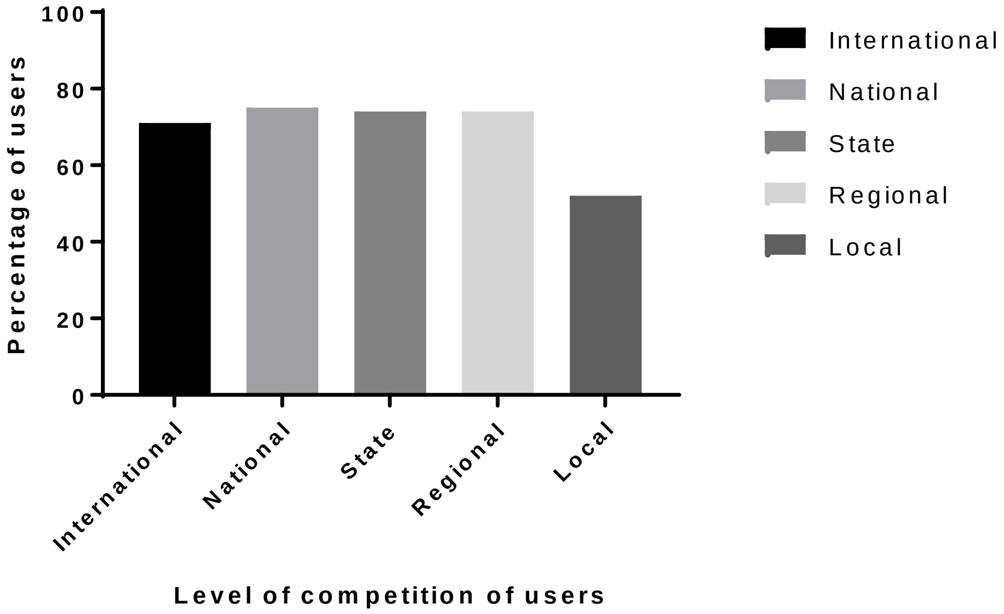

Figure 3.3. Active-land based recovery usage by different levels of competition athletes.

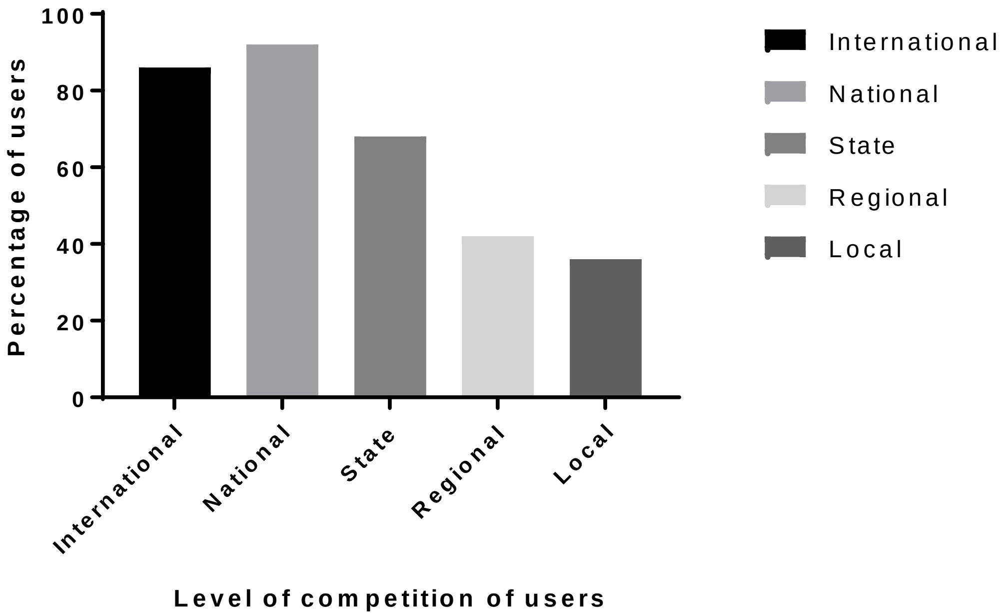

Figure 3.4. Active-water based recovery usage by different levels of competition athletes.

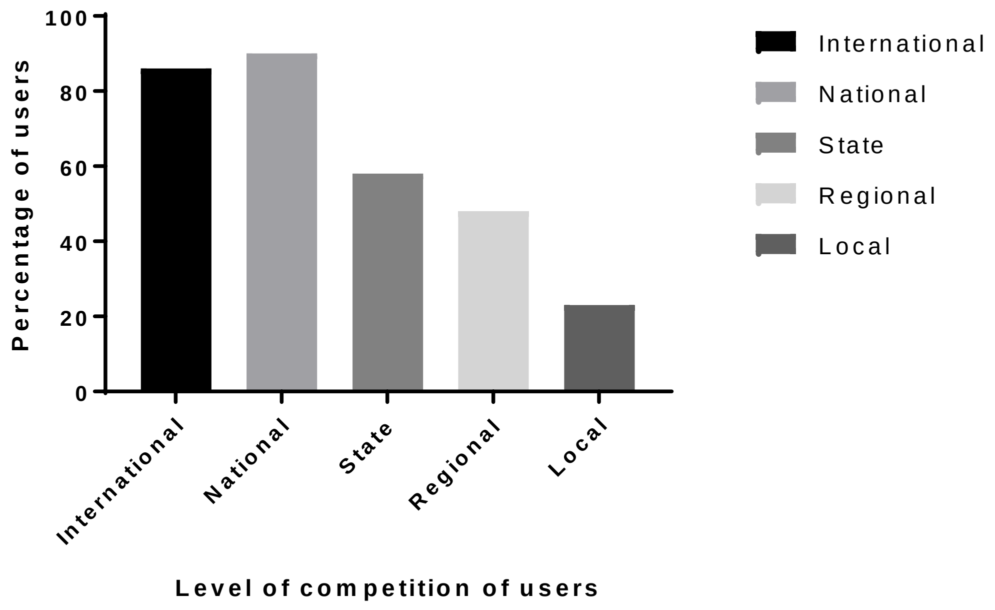

Figure 3.5. Cold water immersion recovery usage by different levels of competition athletes.

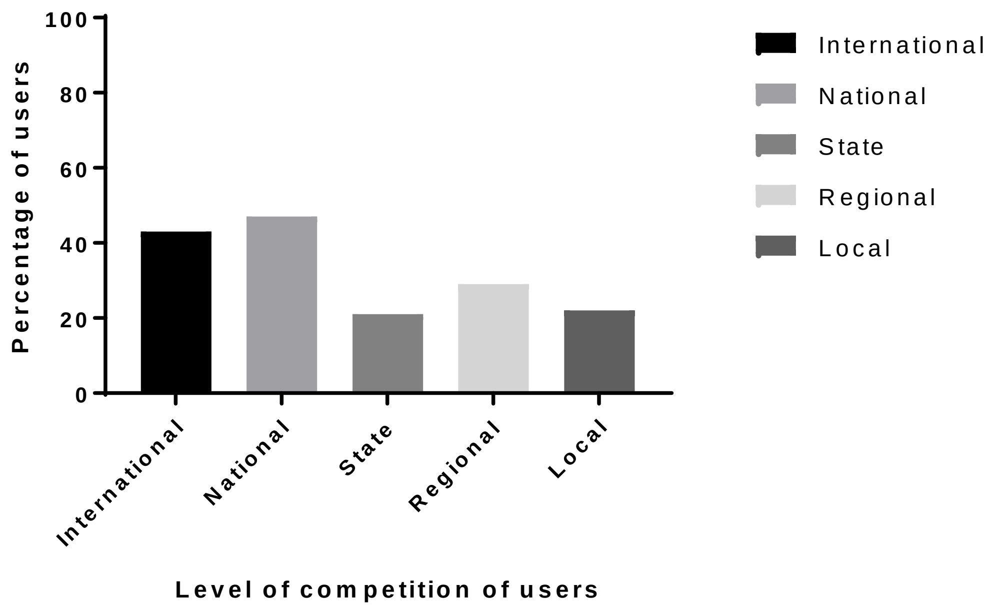

Figure 3.6. Contrast water therapy recovery usage by different levels of competition athletes.

Via free text responses sleep (57%) followed by massage (29%) were considered the most effective recovery techniques by the international athletes, while ice bath (55%) and STR (35%) were considered the most effective by the national athletes. State, regional and local athletes all perceived STR to be the most effective recovery strategy (32%, 42% and 37% respectively) followed by ice bath (26%, 23% and 14% respectively). Forty-three per cent of athletes reported that they did not participate in a post-exercise recovery strategy and of these respondents, self-reported laziness (20%) and time constraints (17%) were the most common reasons provided for not undertaking any post-exercise recovery.

Two-hundred and five athletes completed survey sections 3-7. Across all combined competition levels the athletes that performed STR (M = 4.42, SD = 0.61) and CWI (M = 4.3, SD = 0.57) rated them to be significantly more effective for recovery than the users of ALB (M = 3.63, SD = 0.57, STR and CWI $p < .001$), AWB (M = 4.09, SD = 0.54, STR and CWI $p < .001$) and CWT (M = 4.14, SD = 0.41, STR $p < .001$ and CWI $p = .002$). Active water-based recovery and CWT were also rated significantly more effective than ALB ($p < .001$).

The most highly rated reason for use from the predetermined list for ALB, AWB, STR and CWT was 'decreases muscle soreness' (Table 3.1). This is supported by the free-text responses from participants with the most common psychological reason reported for the effectiveness of each recovery being 'decreases muscle soreness' (excluding AWB and CWI). For CWI the highest rated reason was 'reduces swelling and inflammation', followed by 'decreases muscle soreness' (Table 3.1), which is also supported by the respective free-text answers with the most common physiological reason being 'decreases swelling/inflammation'. The statement 'is what I have seen the elite athletes do' was the lowest rated reason for ALB, AWB, STR and CWT (Table 3.1). ALB had significantly lower ratings than all other recovery strategies for the following reasons of use; 'makes me feel good', 'is what I have seen the elite athletes do', 'will increase muscle performance', 'can improve healing' and 'helps me to train/compete hard again in the next session/game'. Cold water immersion rated significantly higher than all other recovery strategies for the following reasons for use 'is what I have seen the elite athletes do', 'will increase muscle performance' and 'reduces swelling and inflammation'. These ratings were somewhat supported by free-text explanations regarding why the athletes believe that each specific recovery method is or is not effective. When the free-text responses for the effectiveness of each recovery method were classified, the highest percentage of responses for ALB and STR were classified as physical benefits, followed by psychological benefits and physiological benefits. In contrast, for water immersion recovery the highest percentage of responses were classified as psychological benefits (Table 3.2). Table 3.3 shows the details of the most popular recovery sessions used by athletes after a game/match for each recovery type.

Table 3.1

Mean (SD) participant (users of the recovery strategy) ratings (1-5) of the importance of different reasons why specific recovery strategies are used; 1 = not important reason; 3 = neither important nor unimportant reason; 5 = very important reason

	M (*SD*)				
Reasons why a recovery is performed (selected from a list of predetermined options)	Active, land-based recovery (ALB) (*N* = 82)	Active, water-based recovery (AWB) (*N* = 100)	Stretching (STR) (*N* = 144)	Cold water immersion (CWI) (*N* = 89)	Contrast water therapy (CWT) (*N* = 52)
Helps me to wind down and relax	3.5 (0.6)[a]	3.8 (0.8)[b]	3.7 (1.0)[b]	3.3 (0.9)	3.6 (0.6)
Gives me time to socialise with team mates	3.1 (0.7)	3.2 (0.9)	3.3 (1.1)	3.1 (0.9)	3.0 (0.7)
Gives me time to reflect on the training session or match	3.3 (0.7)[c]	3.1 (0.8)	3.3 (1.0)[c]	3.2 (0.9)	3.0 (0.7)
Makes me feel good	3.4 (0.7)[d]	4.0 (0.7)	3.9 (0.9)	3.8 (0.8)	3.8 (0.6)
Is what I have seen the elite athletes do	2.6 (0.8)[d]	3.0 (0.9)	3.1 (1.2)	3.4 (0.9)[d]	2.9 (0.7)
Is something the coach told me to do	3.3 (0.8)	3.3 (0.9)	3.4 (1.1)	3.4 (0.9)	3.3 (0.7)
Will increase muscle performance	3.2 (0.7)[d]	3.6 (0.8)	3.8 (0.9)	4.0 (0.7)[d]	3.6 (0.6)
Speeds up removal of waste product from muscles	3.6 (0.7)[e]	3.8 (0.7)	3.8 (1.0)	3.9 (0.8)	3.9 (0.5)

Decreases muscle soreness	3.9 (0.6)[f]	4.1 (0.7)	4.2 (0.7)	4.1 (0.7)	4.1 (0.4)
Reduces swelling and inflammation	3.4 (0.7)[c]	3.6 (0.7)	3.7 (1.0)	4.2 (0.7)[d]	3.8 (0.6)
Reduces muscle spasms	3.3 (0.7)[abf]	3.8 (0.7)[c]	3.8 (0.9)[c]	3.7 (0.8)	3.5 (0.7)
Increases blood circulation	3.7 (0.7)	3.8 (0.7)[e]	3.6 (1.0)	3.5 (0.9)	3.5 (0.6)
Reduces stress and anxiety	3.2 (0.8)[a]	3.7 (0.8)[e]	3.4 (1.1)	3.3 (0.9)	3.3 (0.6)
Makes me feel energetic	2.9 (0.7)[a]	3.3 (0.8)[b]	3.1 (1.1)	3.0 (0.9)	3.2 (0.6)
Can improve healing	3.3 (0.6)[d]	3.7 (0.7)[bf]	4.0 (0.8)[c]	4.1 (0.7)[c]	3.6 (0.6)
Helps me to switch off	3.0 (0.7)[a]	3.4 (0.9)[bf]	3.0 (1.2)	3.0 (0.9)	3.3 (0.7)
Helps me to be able to train/compete hard again in the next session/game	3.5 (0.7)[d]	3.8 (0.8)	4.1 (0.9)	4.0 (0.7)	4.0 (0.5)
Lowers heart rate	3.2 (0.7)	3.1 (0.9)	3.2 (1.1)	3.1 (0.9)	3.1 (0.7)
Creates a pumping action in the muscles	2.9 (0.7)[a]	3.2 (0.9)[f]	2.8 (1.2)[e]	3.0 (1.0)	3.1 (0.7)

Note. [a]Significantly different from active, water-based; [b]Significantly different from cold water immersion; [c]Significantly different from contrast water therapy; [d]Significantly different from all other recovery strategies; [e]Significantly different from cold water immersion and contrast water therapy; [f]Significantly different from stretching

Table 3.2

Number of total responses and the popular response themes from free text answers for the perceived effectiveness of five recovery strategies.

Category of benefit	Active, land-based recovery (ALB)	Active, water-based recovery (AWB)	Stretching (STR)	Cold water immersion (CWI)	Contrast water therapy (CWT)
Physical	*N* = 23 Improves range of movement (8) Loosens (4) Reduces injury (4)	*N* = 41 Improves range of movement (13) Less stress/strain on body (8) Non weight bearing (6)	*N* = 80 Improves range of movement (25) Reduces tightness (23) Loosens (20)	*N* = 5 Reduces tightness (2)	*N* = 2 Reduces stiffness (2)
Physiological	*N* = 18 Warm/cool down (9) Removes lactic acid (3)	*N* = 29 Cools (11) Blood flow (7) Pressure (4)	*N* = 23 Blood flow (7) Removes lactic acid (3)	*N* = 35 Reduces swelling/inflammation (16)	*N* = 14 Cools (6) Blood flow (3)

	Blood flow (3)		Heals muscles (3)	Cools (11) Removes lactic acid (4)	Reduces swelling/inflammation (3)
Psychological	*N* = 19 Decreases soreness (8) Relax (7) Unwind (4)	*N* = 44 Relax (23) Decreases soreness (10) Freshens (9)	*N* = 51 Decreases soreness (23) Relax (21) Feel better (4)	*N* = 41 Relax (15) Decreases soreness (11) Feels good (10)	*N* = 23 Decreases soreness (9) Relax (6) Feel better (4)
General/unspecified	*N* = 10 It works (3)	*N* = 16 Helps recovery (3) Relatively effective/helpful (2)	*N* = 22 Helps recovery (10)	*N* = 21 Helps recovery (13) Speeds recovery (4) Limited facilities (2)	*N* = 13 Helps recovery (7) Speeds recovery (3)
Sceptical/unsure/neutral	*N*= 13 Don’t feel better (5) Don’t know (3) Sceptical if it works (2)	*N* = 3 Other recovery strategies better (1) Don’t feel better (1) Don’t know (1)	*N* = 5 Don’t feel better (2)	*N* = 4 Don’t know (2) Don’t feel better (1) Am not convinced of the science of it (1)	*N* = 1 Don’t feel better (1)

Did not answer	N = 71	N = 29	N =38	N =31	N = 22

Table 3.3

Most popular post-game/match recovery session details (as assessed by statistical mode).

Recovery (number of respondents)	Recovery activity (number of respondents)	Duration (number of respondents)	Timeframe following game/match (number of respondents)
Active, land-based (ALB; 96)	Walk (69)	10 min (36)	Within 1 hr (32)
Active, water-based (AWB; 89)	Swim (49)	10 min (28)	Within 1 hr (29)
Stretching (STR; 124)	Static (98)	10 min (56)	Within 1 hr (48)
Cold water immersion (CWI; 71)	Cold water bath immersion (44) to the neck (20)	10 min (53)	Within 1 hr (36)
Contrast water therapy (CWT; 45)	Cold water bath immersion (13) to the shoulders/full body (7); hot shower (32) full body immersion (16)	3 cycles (16) of 1 min cold (16): 1 min hot (20)	Within 1 hr (18)

3.5 Discussion

This investigation has identified that a range of recovery strategies are used by athletes across varying team sports and competition levels; and that athletes have varying perceptions of the reason for recovery strategy effectiveness. Fifty-seven percent (mean) of the team sport athletes surveyed performed a recovery strategy after competition and/or training, regardless of competition level. This indicates the majority of athletes acknowledge that recovery is an integral part of performance and training (Coffey et al., 2004) and supports the hypothesis that the majority of athletes perform a recovery. Although, this is the case, this number is lower than expected, based on the important position recovery was believed to play in post-exercise team routines. This high number of recovery strategy non-engagement may be due to a large proportion of these athletes being of a local or regional competition level (87%). This study has also shown that athletes may not always understand the reasons that they are using a recovery, inferring the coach has informed them to use the recovery strategy but they do not know why. Thus it could be recommended that coaches educate athletes about the different recovery strategy options and how they affect athletes. Massage was used as a recovery strategy by all participating international team sport athletes, who also rated massage as the second most effective recovery technique behind sleep, 63% of the national athletes also used massage. It is likely that the higher popularity of use of massage by international athletes (100% use) and national athletes (63% use) in comparison to lower levels of competition athletes (32% state, 45% regional and 22% local) is related to their access to massage therapists who are often members of the support staff.

Stretching was the most frequently used recovery strategy by all competition level athletes (except international, where it was the second most used recovery strategy), partially supporting the hypothesis that STR would be the most used recovery strategy by all level athletes. Stretching was also rated either the most effective (state, regional and local) or second most effective (national) recovery strategy. Furthermore the athletes that used STR rated it to be significantly more effective as a recovery strategy than the users of ALB, AWB and CWT, rejecting the hypothesis that water immersion strategies would be considered to be the most effective recovery strategies. The frequent use of STR by athletes across all competition levels may be attributed to a combination of factors including it can be self-administered, ease of use and accessibility, mainstream popularity and its common practice across the fitness and sporting industries. More specifically, STR requires no equipment, can be performed with minimal space and also has been recommended as a post-exercise recovery strategy across mainstream literature and research for decades (McAtte & Charland, 2014). Food/fluid and sleep/nap were also highly used recovery strategies by all levels of athlete (average 79% and 63% use respectively), this is most likely due to these recovery strategies undertaken as normal daily activities and less so as deliberate choices for recovery as other recovery strategies would be considered to be. This is in contrast to CWI, CWT and AWB strategies that require a deliberate choice and specialised equipment and facilities to complete, as identified in the free-text responses by the athletes in the current study; with one athlete describing AWB as ‘not practical’, two athletes stating that CWI was ‘not always possible’, and another stating that it was ‘a costly and messy’ recovery strategy.

The main reasons provided by the athletes for the effectiveness of STR were physical or psychological in nature, with the most common response themes being ‘improved range of movement’, ‘decreases tightness’ and ‘decreases soreness’ (Table 3.2). Research evidence somewhat supports these notions. Stretching has been found to improve range of motion (Bandy, Irion, & Briggler, 1998; Decoster, Cleland, Altierie, & Russell, 2005) and accordingly decrease tightness of the muscles, although STR does not appear to be effective for reducing/preventing DOMS (Cheung et al., 2003; Herbert & de Norohna, 2007; Torres et al., 2012). Thus showing that athletes may not always understand the influence that STR or other recovery strategies have upon physical recovery.

The second most effective recovery strategy according to the surveyed athletes of this study was CWI (effectiveness rating 4.3/5). The most commonly provided reason for the effectiveness of CWI was to reduce swelling and inflammation (16 free-text responses and importance rating of 4.2/5; Tables 3.1 and 3.2), despite numerous studies showing that CWI does not affect inflammation (Ingram, Dawson, Goodman, Wallman, & Beilby, 2009; Sellwood et al., 2007). A recent study has shown that CWI is not better than ACT for reducing inflammation after strength exercise (Peake et al., 2017). The athletes also reported 'relaxes', 'cools' and 'decreases muscle soreness' (Table 3.2) as common reasons for CWI effectiveness for recovery, with importance also placed on improving healing (Table 3.2). Cold water immersion has been found to reduce core and skin temperature (Clements et al., 2002) and may also provide an enhanced perception of relaxation (Broatch et al., 2014; Moore, 2012). A reduction in muscle soreness is supported by the literature (Diong & Kamper, 2013; Leeder et al., 2012; Poppendieck et al., 2013). Cold water immersion has also been found to induce analgesic effects (Jakeman et al., 2009), which may also improve some sensations associated with tiredness. Notably, CWI received the highest importance rating (3.4/5) of the recovery strategies for the reason 'is what I have seen the elite athletes do' (Table 3.1). The revelation that athletes place importance on whether or not elite athletes are using the CWI recovery also supports the potential belief effect of CWI. While participants indicated that 'improving healing' was an important reason associated with the effectiveness of CWI, there is no scientific evidence to support this. In contrast recent research indicates that regular CWI over 12 weeks suppresses and/or delays the activity of kinases and satellite cells during recovery from strength exercise (Roberts et al., 2015) and is no better than an ACT recovery for reducing cellular stress after resistance exercise (Peake et al., 2017).

Contrast water therapy was considered to be the third most effective recovery strategy with a score of 4.1/5. The most frequently reported and highest rated reason for CWT use and effectiveness was ‘decreases soreness’. This reason is supported by a review of 13 pooled studies whereby CWT decreased soreness at five time points (>6, 24, 48, 72 and 96 hr) in comparison to passive recovery (Bieuzen et al., 2013). Athletes also reported that CWT ‘relaxes’ and ‘cools’, with the assumption that the cold water component is responsible for the cooling sensation as noted previously for CWI; and the hot water component is responsible for the sensation of relaxation (Kovacs & Baker, 2014).

All recovery strategies were found to be most commonly used within 1 hr of completion of exercise. In contrast CWT has been found to be most commonly used immediately post-exercise by elite New Zealand athletes (Hing et al., 2008) and 12 min post-exercise by elite South African rugby union players (Van Wyk & Lambert, 2009). The within 1 hr post-exercise time frame is mostly likely commonly used as some athletes state they complete their recovery strategy at home, so this time frame would be accommodating. It would also be accommodating for higher level athletes that complete their recovery as a team post-match at the playing location. It is likely that athletes also believe completing their recovery strategy after this time may not be as effective, although Dawson and colleagues (2005) found that this may not be the case, finding a ‘next morning’ recovery session to be just as effective as an immediate recovery session. Athletes mainly undertook recovery strategies of 10 min duration, (CWT approximately 6 min). This study found the most utilised durations for CWT to be 1 min in each temperature for 3 cycles whereas Hing and colleagues (2008) found the most used times to be 30 sec in cold, 1 min in hot, for 3 cycles. This study found the most utilised duration for CWI to be 10 min, although Van Wyk and Lambert (2009) found CWI of 2 x 3 min immersions to be most commonly used. Versey and colleagues (2013) state that CWI needs to be 5-15 min and CWT up to 15 min for optimal results. This study has found differences between levels of immersion used for CWI and the cold component of CWT. The differences though are minimal with the regions being neck, shoulder and whole body all being very similar when considering water immersion. Halson (2011) states that whole body immersion be used to increase effectiveness of water immersion protocols.

While this study identifies the use of recovery strategies by team sport athletes and their perceptions of recovery strategies and effectiveness, this study has some limitations. Similar to Venter (2014) the assumption that participants' responses were accurate and the potential influence of other athletes when completing the survey may have influenced the results. Misinterpreting information when completing the survey may also have occurred. While five competition levels were represented in the sampling, most athletes were based in northern Queensland and therefore results are indicative of that region, and may not represent the whole of the country. Another limitation is the difference between the physiological demands of the sports that the participants participated in, although all of the sports represented by regional, state, national and international athletes were also represented by local athletes. Lastly, food/fluid and sleep/nap are recovery processes that all athletes would use post-exercise whether they regard them as a recovery strategy or not, and this may have confounded the usage results for these recovery strategies. Future research should continue to investigate the usage of popular recovery methods, including the use of mental techniques (Keilani et al., 2016) within Australia (coverage of multiple states and cities) and their reasons for use.

3.6 Conclusion

In summary, to the authors' knowledge this is the first study to explore the post-exercise recovery practices of Australian team sport athletes and which identifies and explains their perceptions and preferential use of particular strategies. When asked to rate the five discussed recovery strategies, STR was rated the most effective with ALB considered the least effective by its users. Laziness and time constraints were the main reasons provided by the 43% of athletes who did not undertake any recovery strategy. This study determined that athletes are aware of how they feel following the use of a recovery strategy and they use recovery strategies based on their perceptions, but may not be able to identify why a recovery method is effective or ineffective. This study also highlights how the perceptions of athletes do not always align with scientific evidence. It is suggested that the availability of particular recovery strategies may also impact upon recovery strategy selection. It is encouraged that athletes and coaching staff are informed about the effects different recovery strategies have upon the body to ensure recovery strategies are selected and implemented for the correct reasons.

The survey findings indicated the most used recovery strategies and athlete reasons for recovery usage. Before full analysis was completed the first RCT (Chapter 4) data collection began, based on the conflicting systematic review findings, the initial survey findings, and anecdotal use of water immersion strategies; to identify a superior performance and perceptual recovery strategy after a single game.

Chapter 4

Influence of Recovery Strategies on Performance and Perceptions Following a Single Simulated Team-game Fatiguing Exercise

4.1 Abstract

Many different post-exercise recovery strategies are used by athletes and debate remains regarding their effectiveness. The aim of this study was to compare five post-exercise recovery strategies (CWI, CWT, ACT, COMB and CONT) to determine which is most effective for performance, flexibility and perceived recovery.

Thirty-four recreationally active males undertook a single bout of simulated team-game fatiguing exercise followed by the above listed recovery strategies (randomised, 1 per week). Prior to the fatiguing exercise, and at 1, 24 and 48 hr post-exercise, perceptual, flexibility and performance measures were assessed.

Contrast water immersion significantly enhanced perceptual recovery (*M* (SD) TQR 15.7 (1.9); muscle soreness 2.5 (1.7)) 1 hr after fatiguing exercise in comparison to ACT (13.7 (2.5); 3.8 (1.7)) and CONT (TQR only 14.2 (2.5)). Cold water immersion and COMB produced detrimental jump power performance at 1 hr (CWI relative average 15.3 (2.1) W/kg; relative best 15.9 (2.1) W/kg; COMB relative average 15.4 (2.1) W/kg; relative best 15.9 (2.1) W/kg) compared to CONT (relative average 16.0 (2.3) W/kg; relative best 16.5 (2.3) W/kg) and ACT (relative average 16.1 (2.9) W/kg; relative best 16.7 (2.4) W/kg). No recovery method was different to CONT at 24 and 48 hr for either perceptual or performance variables.

For short term perceptual recovery CWT should be implemented and for short-term CMJ power performance an ACT or CONT recovery strategy is desirable. At 24 and 48 hr no superior recovery method was detected.

4.2 Introduction

High performance athletes employ a variety of recovery strategies (Barnett, 2006; Bieuzen et al., 2013) with the intention of accelerating their recovery (Bleakley & Davison, 2010). A faster recovery timeline is of particular importance amid busy training schedules (Poppendieck et al., 2013) where the inability to sustain a high volume of work without interruption is often thought to hinder the progress of the athlete. The efficacy of numerous recovery strategies has been explored in scientific studies and also in practical sport applications, with some strategies being used without compelling supportive evidence (Bleakley & Davison, 2010; Cochrane, 2004; Hing et al., 2008). Water immersion recovery strategies such as CWI and CWT are used by athletes across a range of levels to quicken post-exercise recovery (Hing et al., 2008; Versey et al., 2013; Wilcock et al., 2006).

Cold water immersion reportedly minimises muscle oedema and provides analgesic effects post-exercise (Wilcock et al., 2006). Contrast water therapy is the alternation between hot and cold water (Hing et al. 2008) and is purported to decrease lactate accumulation (Coffey et al., 2004), inflammation, oedema, pain and muscle stiffness (Hing et al., 2008). The common explanation for its effectiveness is based on the alternation between vasodilation and vasoconstriction in response to hot and cold water (Hing et al., 2008).

An ACT recovery strategy is a simple and commonly used technique that involves the completion of low intensity exercise. The active recovery strategy has been suggested to increase blood flow and range of motion (Gill et al., 2006). Various findings surround the use of an ACT recovery strategy. An ACT recovery at 40% of peak running speed for 15 min was not shown to improve muscle soreness and performance in comparison to CONT (Coffey et al., 2004), while another study that found that cycling to exhaustion decreased after ACT in comparison to after CWI and CWT (Crampton et al., 2013).

A number of recovery strategy reviews are inconclusive as to whether CWI or CWT are effective recovery methods following exercise and sport (Bleakley & Davison, 2010; Cochrane, 2004; Hing et al., 2008). Other recent reviews have shown CWI to reduce delayed onset muscle soreness (Diong & Kamper, 2013) and fatigue (Nédélec et al., 2013). Bieuzen and colleagues (2013) found CWT to be no better than CWI, warm water immersion, ACT and STR, although better than passive rest. Torres and colleagues (2012) also found CWI, ACT and STR to be generally not effective or inconsistent in improving muscle soreness or strength. Chapter 2 of this thesis (systematic review) also indicates the uncertainty regarding the effectiveness of CWI, CWT and ACT upon performance and perceptual recovery. The systematic review findings indicate that CWI was effective in comparison to CONT for performance recovery only 17%, and for perpetual recovery only 27% of the time. Similarly, CWT was effective for performance in comparison to CONT 24% of the time, and for perceptual recovery 27% of the time. The systematic review also identified that most of the time an ACT recovery had no significant effect on performance and perceptual recovery compared to CONT. Thus there is conflicting research surrounding the use of water immersion strategies, and limited evidence supporting the use of an ACT recovery, and further investigation into their effectiveness is required.

A limited number of studies have investigated the combination of CWI and ACT recovery strategies (COMB), with mixed results (Crampton et al., 2014; Ferreira et al., 2011; Getto & Golden, 2013; Hudson et al., 1999; Kinugasa & Kilding, 2009). The combined recovery has been shown to be effective at removing blood lactate (Ferreira et al., 2011; Hudson et al., 1999), and eliciting positive perceptions of recovery (Kinugasa & Kilding, 2009) in comparison to CONT. In contrast it has been shown to have no effect on Wingate peak power (30 min post-exercise) in comparison to ACT and CONT, to be significantly better than CWI for Wingate mean power at 30 min post-exercise (Crampton et al., 2014) and to be of no difference in comparison to CWI and CONT for restoration of speed, power and perceived soreness 24 hr post-exercise (Getto & Golden, 2013). Further research is required to determine the efficacy of this recovery strategy.

Based on the initial findings of Chapter 3 that indicated there was a high usage of CWI, CWT, ACT and AWB (COMB in Chapters 4 and 5), along with the anecdotal use of water immersion strategies; the four recovery strategies of CWI, CWT, ACT and COMB were chosen to be investigated further in this RCT. The purpose of this study is to investigate the effects of five recovery methods (CWI, CWT, ACT, COMB and CONT) on indicators of performance, flexibility, and perceptual recovery following fatiguing exercise. Water immersion strategies and ACT are hypothesised to be superior to CONT for performance and perceptual indices of recovery over the 48 hr time period, based on current available evidence (Brophy-Williams et al., 2011; Crampton et al., 2013; King & Duffield, 2009) and the above discussed physiological mechanisms.

4.3 Methods

Thirty-four recreationally active, uninjured, apparently healthy males voluntarily participated in the study (age: *M* = 27, *SD* = 6 years; height: *M* = 180, *SD* = 8 cm; weight: *M* = 80, *SD* = 9 kg; predicted $\dot{V}O_2max$: *M* = 43, *SD* = 6 ml/kg/min). Sample size estimation was conducted *a priori* using G* Power (Version.3.1.9.2). These calculations indicated a sample size of 24 was required (power = 0.8; $p = 0.05$; effect size = 0.25). Thus the target sample size was 30 participants, allowing for 6 non-completions. Participants were not from a particular sport and were recruited via the ethics approved process of word of mouth and multimedia advertising including flyers, emails, newspaper and social media. All participants were able to complete the fatiguing exercise, participated in regular aerobic exercise and were not elite athletes. The retention rate for the study was 85% with 15% unable to complete the full five weeks of testing. Reasons why the five participants were unable to complete all scheduled testing sessions related to external factors (four became injured from external events and one started a new job and was unable to complete all scheduled sessions); however their data were included for completeness in quantitative analysis of the completed recovery protocols. Contact sport athletes were excluded from the study if they were participating in contact sport during the testing period, due to the confounding potential for muscle soreness caused by these sports. Participants were instructed to abstain from exercise and alcohol 24 hr before the first session until the conclusion of the 48 hr post testing session, and to abstain from food 2 hr and caffeine 4 hr prior to sessions. Exercise diaries were completed throughout the testing period and were analysed to confirm consistency of exercise throughout the testing period and adherence to the research project instructions. Participants were informed, verbally and in writing, of the procedures to be undertaken and provided written informed consent prior to participation. Ethics approval was granted by the Human Ethics Committee of James Cook University, H5415 (Appendix D).

Participants performed two familiarisation sessions. The first session included a standardised, generalised warm up, 3 x 20 m maximal sprints for the determination of peak speed, and a practice of the repeated sprint ability (Elias et al., 2012; Elias et al., 2013) and CMJ adapted from Elias and colleagues (2012) and King and Duffield (2009). The repeated sprint ability test has a reported coefficient of variation of 2.3%, and total sprint time (as used in this Chapter and Chapter 5) is strongly correlated to fastest 20 m sprint time (r = .66; Pyne, Saunders, Montgomery, Hewitt, & Sheehan, 2008). During the second session participants completed the generalised warm up followed by a practice of the sit and reach flexibility test (Higgins, Climstein, & Cameron, 2013), completion of the multi-stage fitness test to assess aerobic capacity (Leger, Mercier, Gadoury, & Lambert, 1988), practice of the fatiguing exercise and familiarisation with the Daily Analyses of Life Demands for Athletes (DALDA) scale (Rushall, 1990), muscle soreness scale (Pointon & Duffield, 2012) and TQR scale (Kenttä & Hassmén, 1998). The five recovery protocols were also explained at this time.

At the start of each testing session, participants were assessed for hydration status via urine specific gravity measurement with the use of a handheld refractometer (John Morris Scientific Pty Limited, Japan), had their body mass measured (Tanita, TBF5383611, Japan) for subsequent power calculations for the CMJ test, and completed the DALDA questionnaire, muscle soreness scale and TQR scale. The mean inter-assay coefficient of variation for hydration across all sessions was 0.8% (average range over five conditions 1.02 - 1.03), and therefore was unlikely to impact upon results. The mean inter-assay coefficient of variation across all five sessions for CMJ (average and best) and for TQR was 6% and 4% respectively, showing high reproducibility of the test conditions and participant effort.

The DALDA questionnaire lists a series of life-stress and symptoms of stress items, where participants label each item with a letter; "a" means worse than normal, "b" means normal and "c" indicates better than normal (Rushall, 1990; Appendix E). The muscle soreness scale was a 10 point Likert scale from 0 (no soreness) to 10 (very very sore; Pointon & Duffield, 2012; Appendix F). The TQR was a scale that ranged from 6 (below very very poor recovery) to 20 (above very very good recovery; Kenttä & Hassmén, 1998; Appendix G). For these two perceptual scales, participants were allowed to give numbers that were not whole numbers. A generalised warm up was undertaken prior to completion of sit and reach flexibility, repeated sprint ability and the CMJ tests. The sit and reach test was performed three times, with the best measurement recorded for analysis. The mean inter-assay coefficient of variation for sit and reach flexibility across all five sessions was 10%, showing high reproducibility of the test conditions. Participants undertook the repeated sprint ability test, which included a maximal 20 m sprint every 30 sec with six repetitions (Elias et al., 2012; Elias et al., 2013). The CMJ protocol included five jumps of maximal height on a mat, one jump every 15 sec (Elias et al., 2012; King & Duffield, 2009), with jump height and power recorded. Sprint and jump performance were measured with the Swift timing gates and mat (Swift Performance Equipment, QLD, Australia).

Participants completed a 3 x 15 min simulated team-game circuit adapted from Singh and colleagues (2010) and Bishop and colleagues (2001) as the fatiguing exercise protocol. The fatiguing exercise involved a circuit undertaken each min which included sprinting, striding, jogging, walking and agility, with bag tackles completed on every fifth rotation (Singh, Guelfi, Landers, Dawson, & Bishop, 2010) and bumps (participants were contacted with bump pads three times on each side of the body as adapted from Singh et al., 2010) on the 15th rotation (Figure 4.1). After 15 rotations participants rested for five min before repeating the process two more times. Heart rate was monitored throughout (Polar Electro Oy, Finland) and Borg's RPE (Borg, 1982; Appendix F) was recorded at the completion of the third round. The mean inter-assay coefficient of variation for RPE and average HR across all five sessions was 8% and 4% respectively, showing high reproducibility of the test conditions and participant effort.

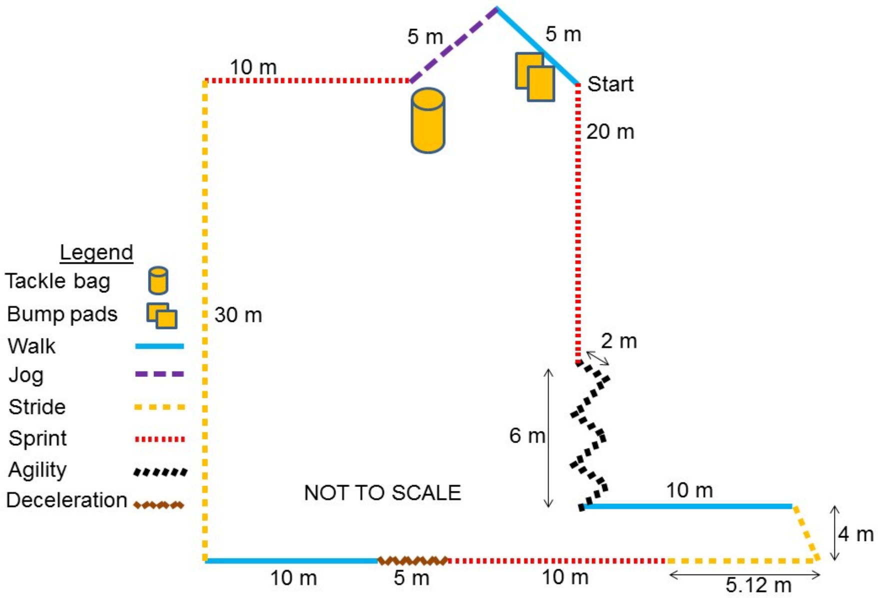

Figure 4.1. Diagram of the simulated team-game fatiguing circuit adapted from Singh and colleagues (2010) and Bishop and colleagues (2001).

Following a 10 min rest, participants completed a 5 min jog at 20% peak speed (adapted from Vaile and colleagues, 2008a), peak speed was calculated from the maximal sprints in the first familiarisation session. This jog was implemented for practical reasons, as many teams would undertake an active component prior to recovery. Participants then undertook their randomly assigned recovery protocol, CWI, CWT, ACT, COMB or CONT. All recovery strategies were undertaken for 14 min, as a number of water immersion research studies reviewed in the systematic review of Chapter 2 used this duration (Argus et al., 2016; Elias et al., 2012; Elias et al., 2013). Cold water immersion included being seated in an inflatable bath (iCool Sport, Shenzhen, China), with shoulders immersed at a temperature of 15 °C (Vaile et al., 2008a Vaile, Halson, Gill, & Dawson, 2008b). Contrast water immersion included alternating between a cold bath set to 15 °C and a hot bath set to 38 °C (iCool sport, Shenzhen, China), both to shoulder immersion depth (Vaile et al., 2008b), with participants instructed to change baths every 1 min. Active recovery included outdoor jogging around a marked and measured track at 35% peak speed as adapted from King and Duffield (2009) with continual feedback to maintain the desired speed. The COMB recovery was performed as per the cold water immersion protocol with the addition of low intensity leg movement (flexion and extension at the hips and knees) while seated inside the cold bath. A typical ACT recovery was not able to be undertaken in water, as thermoregulated individual pools were used in preference to a swimming pool. Participants' heart rate was recorded every 10 sec of the COMB recovery and averaged 48% (5%) of their max heart rate. The CONT protocol involved participants sitting on a chair, with as little movement as possible. All recovery protocols and testing procedures were performed outdoors at natural environmental temperatures with no significant difference found over the five sessions for temperature (p = .230; average range over five conditions 22.6 °C - 23.9 °C) and humidity (p = .955; average range over five conditions 71.9% - 73.9%).

After each recovery protocol, participants undertook seated rest until 1 hr had lapsed from completion of the fatiguing exercise. Participants then completed the TQR and muscle soreness scale, performed the standardised warm up and completed the sit and reach, repeated sprint ability and CMJ tests (approximately 30 min combined). The entire duration of the testing session was approximately 3 hr.

Participants returned at 24 and 48 hr post completion of the fatiguing exercise for the following tests: urine specific gravity, DALDA, muscle soreness scale, TQR; and the same generalised warm up, sit and reach, repeated sprint ability and CMJ tests. At the conclusion of all testing participants were asked which recovery strategy they thought was most effective and which was least effective and to give reasons why. Participants were blinded to the results of the performance tests. The entire testing process was repeated each week until participants had completed all five randomly ordered recovery strategies (excluding those who were unable to finish). Participants performed testing at approximately the same time each day. A verified randomisation tool (random.org) was used for randomisation of recovery strategy order for participants.

4.3.1 Statistical analyses

Data were analysed using the Statistical Package for Social Sciences (IBM SPSS Incorporation, Version 22, Chicago, Ill, USA) via two-way (time x recovery) repeated measures ANOVA and *post hoc* Tukey HSD tests. Data were presented as *M*, (*SD*) with alpha set at .05. All results are interaction results unless specified. Minimum detectable change (MDC) was also calculated for both the group recovery and interaction changes and individual participant interaction changes (Silva et al., 2015). The interaction MDCs and the % of individual participant interactions that exceeded the MDC are included in text and Table 4.1 (values were not assessed for the three participants that did not complete most weeks of testing). The following variables were analysed; RPE, HR, hydration, DALDA scale, muscle soreness, TQR, best sit and reach performance, total repeated sprint time, relative (normalised for mass) average and best jump power performances. The following recovery related components of the DALDA scale were analysed (letter responses were converted to ordinal numbers for analysis): muscle pains, need for rest, recovery time, unexplained aches, between session recovery and swelling. Incomplete data points were estimated for by using the recovery and time specific average (specifically for the 5 participants that did not undertake all recovery strategies).

4.4 Results

A recovery strategy main effect was evident for DALDA item “need for rest” with CWI (2.0, where 1 is worse than normal, 2 is normal and 3 is better than normal) eliciting less need for rest than CWT (1.8, p = .022). As an overall time effect, the response to the DALDA scale muscle pain was significantly worse at 24 hr post-exercise (1.8) in comparison to 48 hr (2.0, $p < .001$). Swelling was significantly greater at 48 hr (2.0) compared to 24 hr (2.0, $p = .038$) via the DALDA perceptual scale (main time effect).

No interaction or recovery strategy group MDCs were indicated for sit and reach, total sprint time, relative average and best power, TQR and muscle soreness. The percentage of individual participant interactions that exceeded the interaction MDC (ranging from 8-17%) and the most common findings are reported in Table 4.1

Table 4.1

Participant minimum detectable change results

Variable	Interaction MDC value	% of individual participant interactions that MDC is exceeded	Most common results in comparison to CONT
Sit and reach flexibility	5.7	16	CWI mostly detrimental
Total repeated sprint time	2.8	8	CWT mostly improved
Relative average CMJ power	1.8	17	CWT and COMB mostly detrimental
Relative best CMJ power	1.8	17	CWT mostly detrimental
Total quality recovery	5.1	9	ACT mostly improved
Muscle soreness	4.3	12	COMB mostly detrimental

Note. CMJ = countermovement jump; MDC = minimum detectable change; CONT = control; CWI = cold water immersion; CWT = contrast water therapy; COMB = combined recovery; ACT = active recovery

No change in sit and reach flexibility was found across conditions or times (Table 4.2). There was a main time effect for total sprint times, with sprint time at 1 hr (21.9 sec) significantly slower in comparison to baseline (21.3 sec, $p < .001$), 24 hr (21.4 sec, $p = .004$) and 48 hr (21.3 sec, $p < .001$) with no interaction, or recovery strategy main effects evident (Table 4.2).

Table 4.2

Sit and reach flexibility and total sprint time assessed at baseline and 1 hr, 24 hr and 48 hr after fatiguing exercise for each of the different recovery strategies.

	M (*SD*)				
Measures	Control (CONT)	Cold (CWI)	Contrast (CWT)	Active (ACT)	Combined (COMB)
Sit and Reach (cm)					
Baseline	31.7 (8.1)	32.1 (9.0)	31.8 (9.3)	31.8 (9.0)	32.0 (9.7)
1 hr post	32.2 (7.8)	31.8 (9.2)	32.3 (9.1)	32.1 (8.5)	32.2 (8.9)
24 hr post	31.4 (8.6)	31.3 (9.5)	31.9 (9.7)	31.9 (9.3)	31.8 (9.7)
48 hr post	32.5 (8.5)	31.5 (9.2)	31.7 (9.5)	31.9 (9.1)	31.7 (9.8)
Total repeated sprint time (s)					
Baseline	21.4 (1.7)	21.0 (1.0)	21.3 (1.1)	21.2 (1.2)	21.4 (1.3)
1 hr post[ab]	21.9 (2.4)	22.0 (1.3)	21.8 (1.4)	21.6 (1.4)	22.3 (1.5)
24 hr post	21.4 (1.4)	21.5 (1.3)	21.5 (1.4)	21.4 (1.3)	21.4 (1.1)
48 hr post	21.6 (1.8)	21.2 (1.4)	21.4 (1.3)	21.2 (1.3)	21.2 (1.0)

Note. Main time effects: [a]Significant difference in comparison to baseline and 48 hr post fatiguing exercise values. [b]Significant difference in comparison to 24 hr post fatiguing exercise values.

A main effect for recovery strategy was found for average and best power, with ACT found to significantly improve jump performance variables (relative average power 16.1

W/kg and relative best power 16.6 W/kg) in comparison to COMB (relative average power 15.7 W/kg, p = .012 and relative best power 16.2 W/kg, p = .004) and CWT (relative best power 16.3 W/kg, p = .040). Cold water immersion and COMB resulted in significantly reduced power (average and best) at 1 hr compared to CONT and ACT, (Table 4.3 and Figure 4.2). Jump power variables at 1 hr were significantly reduced compared to other time points for CWI (compared to baseline, 24 hr (excluding best power) and 48 hr), and average power after COMB (compared to baseline and 48 hr) with no effect of time evident for CWT, ACT or CONT (Table 4.3 and Figure 4.2). A main effect for time occurred for jump power with a significant reduction at 1 hr (relative average power 15.7 W/kg and relative best power 16.2 W/kg) compared to baseline (relative average power 16.0 W/kg, p = .002 and relative best power 16.5 W/kg, p = .001; Table 4.3).

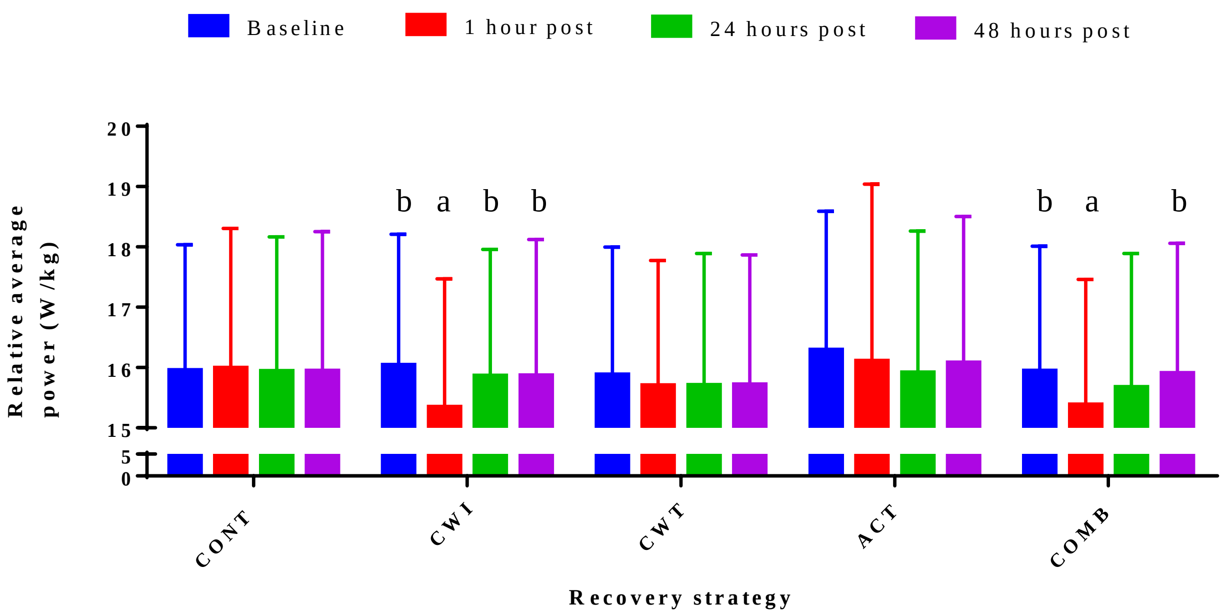

Figure 4.2. A comparison of countermovement jump relative average (*SD*) power of all recovery strategies across all time points

a Significant difference from CONT and ACT 1hr post. b Significantly different from respective 1 hr post values

Table 4.3

Countermovement jump relative best power (W/kg) assessed at baseline and 1 hr, 24 hr and 48 hr after fatiguing exercise for each of the different recovery strategies.

	M (*SD*)				
Time	Control (CONT)	Cold (CWI)	Contrast (CWT)	Active (ACT)	Combined (COMB)
Baseline	16.5 (2.1)	16.6 (2.2)	16.4 (2.1)	16.8 (2.3)	16.4 (2.1)
1 hr post[c]	16.5 (2.3)	15.9 (2.1)[ab]	16.2 (2.0)	16.7 (2.4)	15.9 (2.1)[b]
24 hr post	16.5 (2.2)	16.3 (2.1)	16.2 (2.3)	16.5 (2.4)	16.2 (2.2)
48 hr post	16.4 (2.3)	16.4 (2.4)	16.2 (2.1)	16.6 (2.5)	16.4 (2.3)

Note. Interaction effects: [a]Significant difference in comparison to respective baseline and 48 hr post fatiguing exercise values. [b]Significant difference in comparison to active and control recovery strategies. Main time effects: [c]Significant difference from baseline.

Active and CONT were found to have significantly reduced TQR at 1 hr in comparison to CWT (Table 4.4). The ACT and CWI ratings at 1 hr were no different from CONT with significantly decreased ratings from their respective baseline and 48 hr values (Table 4.4). At 24 hr ACT and CONT were both still reduced in comparison to baseline and 48 hr (CONT only; Table 4.4). The COMB and CWT protocols did not show significant decreases in TQR as a result of the fatiguing exercise across any time points (Table 4.4). Total quality recovery demonstrated a significant main effect for time with recovery rates significantly lower at 1 hr (14.6, where 6 is below very, very poor recovery and 20 is above very, very good recovery) and 24 hr (15.1) compared to baseline (16.4, 1 hr $p < .001$, 24 hr $p = .002$) and 48 hr (15.9, 1 hr and 24 hr $p < .001$), with TQR ratings restored to baseline levels by 48 hr (Table 4.4).

Table 4.4

Total quality recovery assessed at baseline and 1 hr, 24 hr and 48 hr after fatiguing exercise for each of the different recovery strategies.

	M (*SD*)				
Time	Control (CONT)	Cold (CWI)	Contrast (CWT)	Active (ACT)	Combined (COMB)
Baseline	16.3 (2.0)	16.5 (2.3)	16.3 (2.5)	16.5 (2.3)	16.2 (2.3)
1 hr post[d]	14.2 (2.5)[ab]	14.4 (2.5)[a]	15.7 (1.9)	13.7 (2.5)[ab]	15.0 (2.1)
24 hr post[d]	14.3 (2.6)[a]	15.6 (2.3)	15.2 (1.8)	15.0 (2.7)[c]	15.6 (2.0)
48 hr post	15.9 (2.3)	16.0 (2.1)	15.9 (1.7)	15.7 (2.5)	16.1 (1.8)

Note. Interaction effects: [a]Significant difference in comparison to respective baseline and 48 hr post fatiguing exercise values. [b]Significant difference in comparison to contrast recovery. [c]Significant difference from respective baseline measures. Main time effects: [d]Significant difference in comparison to baseline and 48 hr post fatiguing exercise values.

At 1 hr, CWT resulted in significantly less muscle soreness than ACT (Table 4.5). Muscle soreness in the CWI and ACT recovery strategies showed no difference to CONT with significantly higher muscle soreness scores than baseline at 1 hr and 24 hr (Table 4.5). At 48 hr ACT showed no difference to CONT with both recovery strategies showing values significantly better than their respective 1 hr readings (Table 4.5). There was no difference in muscle soreness across time for the CWT and COMB protocols. A significant main effect for time occurred for muscle soreness with scores significantly higher at 1 hr (3.3, where 0 is no pain and 10 is very, very sore) and 24 hr (3.1) compared to baseline (1.8, 1 hr and 24 hr $p < .001$) and 48 hr (2.3, 1 hr $p = .001$ and 24 hr $p < .001$; Table 4.5).

Table 4.5

Muscle soreness assessed at baseline and 1 hr, 24 hr and 48 hr after fatiguing exercise for each of the different recovery strategies.

	M (*SD*)				
	Control	Cold	Contrast	Active	Combined
Time	(CONT)	(CWI)	(CWT)	(ACT)	(COMB)
Baseline	1.7 (1.8)	1.8 (2.0)	2.1 (1.9)	1.5 (1.6)	2.0 (2.1)
1 hr post[d]	3.6 (2.2)[a]	3.3 (2.0)[b]	2.5 (1.7)	3.8 (1.7)[ac]	3.0 (1.8)
24 hr post[d]	3.2 (1.9)[b]	3.3 (2.1)[b]	2.9 (1.8)	3.3 (1.8)[b]	2.7 (1.5)
48 hr post	2.0 (1.7)	2.4 (1.7)	2.5 (1.6)	2.4 (1.9)	2.1 (1.7)

Note. Interaction effects: [a]Significant difference in comparison to respective baseline and 48 hr post fatiguing exercise values. [b]Significant difference from respective baseline measures. [c]Significant difference in comparison to contrast recovery. Main time effects: [d]Significant difference in comparison to baseline and 48 hr post fatiguing exercise values

At the conclusion of all protocols, CWT was rated as the most effective recovery strategy by the most participants (50%), followed by COMB and CWI (29% each). The top response given for why these recovery strategies were favoured was “felt better/good”, with “decrease in muscle soreness” also noted for CWI. Participants rated CWI the least effective recovery strategy (30%) for reasons such as “felt bad for the day after”, followed by ACT (26%), with the most common responses of “felt like more exercise” and “felt stiff”.

4.5 Discussion

This study compared a variety of post-exercise recovery strategies with results suggesting differing effects on perceptions of recovery and subsequent performance short term. At 1 hr CWI and COMB recovery strategies showed detrimental performance results in comparison to ACT and CONT. One hour following fatiguing exercise, CWT elicited superior perceptions of recovery. However, there was no difference between the five recovery strategies at 24 and 48 hr for perceptual or performance recovery. The hypothesis that water immersion strategies and ACT would be superior to CONT for performance and perceptual recovery over the 48 hr, was only partially fulfilled with CWT eliciting superior perceptions of recovery 1 hr post-exercise in comparison to CONT.

Average jump performance was hindered significantly at 1 hr after CWI and COMB in comparison to CONT, ACT and respective baseline measures. It is likely that 1 hr was not sufficient time for the muscles to rewarm, with a large number of participants noting stiffness in their legs when undergoing testing 1 hr after the cold water strategies, even after undertaking a short warm up. Other studies have shown CONT to be superior to CWI for cycling peak power and total work 1 hr post-exercise (Crowe et al., 2007) and 30 min post-exercise for swim performance (Parouty et al., 2010). Crowe and colleagues (2007) reasoned that cold water may cause peripheral vasoconstriction and less blood flow to major muscle groups which combined with insufficient time for muscles to rewarm, could have attributed to the decreased power performance at 1 hr and overall after cold water immersion recovery strategies. As in this study, Kinugasa and Kilding (2009) found a combined recovery of ACT and CWI did not alter vertical jump measures at 24 hr in comparison to CONT and CWT recovery strategies and that performance had returned to baseline values, indicating that irrespective of recovery strategy, athletes had recovered by 24 hr.

Despite not feeling recovered after ACT, the participants achieved the same jump power performance results as the CONT protocol which was significantly superior to CWI and COMB. It is not specifically known why ACT would induce these positive results in comparison to other recovery strategies, except as discussed earlier that there is a potential increase in blood flow and oxygen to the muscles post-exercise, which may assist with recovery.

As an acute post-experiment comparison, athletes indicated that the CWT was the most positively perceived recovery strategy. This is most likely because CWT resulted in significantly reduced perceptions of muscle soreness and TQR ratings at 1 hr in comparison to CONT (TQR only) and ACT. Similar findings have been reported with CWT producing better perceptual recovery following anaerobic exercise in comparison to ACT and CONT recovery strategies (Sayers, Calder, & Sanders, 2011), and CWT producing superior perceptual benefits of recovery in elite netball athletes following a fatiguing netball circuit in comparison to CONT (Juliff et al., 2014). Another study reported reduced perceptions of recovery 48 hr post CWT in comparison to CWI (Elias et al., 2013). Despite the positive TQR and muscle soreness results in the current study, after CWT participants noted a significantly higher "need for rest" (DALDA) in comparison to CWI. Reasons for this response are not immediately clear. It is believed from participant feedback that the reason CWT was favoured over all other recovery strategies, was due to the inclusion of heat. Participants often noted CWT having a relaxing, therapeutic effect upon the body, which has been supported by other authors (Kovacs & Baker, 2014), and may be the primary factor in the common perception of the effectiveness of this recovery strategy. The high perception of effectiveness may also be a placebo effect due to the significant use of CWT within society and its assumed effectiveness. Athletes may have also had preconceived beliefs about the effectiveness of CWT and may feel more comfortable or familiar with this type of recovery.

Participants rated COMB as the second most effective recovery strategy. A number of studies support the positive perceptual findings of a COMB recovery strategy (Kinugasa & Kilding, 2009; Hudson et al., 1999). Reasons given for why a COMB protocol is more effective in preventing decreased perceptual recovery than CWI, ACT and CONT include the action of hydrostatic pressure influencing an oscillating shift in blood volume due to movement of the lower limb (Hudson et al., 1999), which may assist with increasing blood flow and thus greater perceptual benefits. Studies have found a combined recovery of ACT and CWI to remove lactate faster than CONT (Hudson et al., 1999; Ferreira et al., 2011). Furthermore, a COMB recovery may cause a reduction in neuron transmission speed within the body which decreases experienced pain (Meeusen & Lievens, 1986), this might explain the common analgesic effects reported for cold water immersion strategies (Jakeman et al., 2009). Christie and colleagues (1990) found that cycling in water in comparison to the same cycling protocol on land increased central blood volume and decreased vascular resistance. Furthermore a COMB recovery strategy may assist to reduce muscle soreness and sensations of fatigue caused by oedema, faster than a land based active recovery (Hudson et al., 1999). Myer and colleagues (1998) reason that rapid post-exercise cooling strategies utilising cold water may provide a means to restore homeostasis and reduce intramuscular temperature. It is feasible that this mechanism applies also to the COMB recovery strategy.

Cold water immersion caused participants to have significantly less need for rest, although other perceptual measures were shown to be decreased after CWI in comparison to rest, with participants still noting significantly worse perceptual recordings at 24 hr in comparison to baseline. In contrast Ingram and colleagues (2009) found CWI to positively influence perceptions of muscle soreness at 24 hr in comparison to CONT and CWT. Bailey and colleagues (2007) also found CWI to significantly reduce muscle soreness ratings at 1, 24 and 48 hr. Cold water immersion also produced significant perceptual benefits in a number of other studies (Ascensãão et al., 2011; Elias et al., 2013). As previously stated CWI treatments are considered to be effective for perceptual recovery due to analgesic effects. When participants were asked which recovery strategy they found least effective approximately 1 in 3 participants stated CWI, with some participants reporting feeling numb, stiff and sore. This was not only immediately after immersion, with one participant specifically stating soreness 1 day post testing and another participant noted unusual muscle cramps between their 24 and

48 hr follow up sessions. These statements from participants' support why they did not perceive benefit from the CWI protocol. The differences in protocols may have led to the differences in perceptual findings between our study and those of other studies, as all protocols showing positive perceptual findings from CWI (Bailey et al., 2007; Elias et al., 2013; Ingram et al., 2009) did not implement full body immersion, with most being to the hip or umbilicus and also were immersed in colder water (10-12 ºC) with most having an immersion for 10 min compared to 14 min in the current study.

Active recovery was unable to prevent a significant increase in soreness or a significant reduction in the perception of recovery at 1 and 24 hr as compared to baseline. At 1 hr, the perception of recovery following ACT was also significantly worse than after CWT, as reported previously (King & Duffield, 2009). During an active recovery participants are moving and expending energy so it is likely they do not yet feel recovered at 1 hr post fatiguing exercise.

Main time effects showed that muscle soreness and TQR ratings were detrimentally affected at 24 hr in comparison to baseline and 48 hrs, but performance was not. Thus we can conclude that the fatiguing exercise was sufficient to induce perceptual decrements at 1 and 24 hr but not performance decrements at 24 and 48 hr. King and Duffield (2009) also found similar findings with detrimental perceptual differences identified and performance unaffected at 24 hr post fatiguing exercise.

When interpreting the significant *p* value interaction effects, it is important to consider whether these effects are supported by MDCs; and whether the differences are practically (or clinically) meaningful in applied sporting context. The 1 hr relative jump power for ACT was significantly better than CWI ($p < 0.05$) by 0.8 W/kg and COMB ($p < 0.05$) by 0.7 W/kg; and CONT was significantly better than CWI ($p < 0.05$) by 0.7 W/kg and

COMB ($p < 0.05$) by 0.6 W/kg at the same time point. While these group mean differences are less than that needed for a minimal detectable change (1.8 W/kg difference), this 4-5% difference in relative average power is likely to have a practical impact. The 4-5% improvement in jump performance may enable an athlete to jump higher than an opponent and therefore may result in a gain in ball possession during contested play. At 1 hr TQR following CWT was significantly better in comparison to ACT ($p < 0.05$) and CONT ($p < 0.05$) by approximately 2 ratings on the 20-point TQR scale, with CWT recovery reported as good-very good, as compared to the ACT and CONT ratings of reasonable-good. Similarly, the 1 hr muscle soreness following CWT was significantly better than ACT ($p < 0.05$) by approximately 1 point on the 10 point scale. Again, these mean differences in TQR and muscle soreness do not meet that which is needed to identify as a MDC (5.1 and 4.3 respectively); however in a practical setting this difference in recovery perception is likely to impact on the player's actions and attitudes leading up to the next training session.

Of note in this study was that while no significant MDCs were evident for group interaction or recovery data, across all variables between 8-17% of individual participant interactions exceeded the relevant MDC (Table 4.1); and these individual responses did not always align with the overall group response. For example, while as a group 1 hr jump performance was better following CONT and ACT compared to CWI and COMB; the majority of the 17% of individual significant MDCs for this variable showed CWT to be detrimental compared to CONT. This indicates that athletes appear to have very individualised responses to recovery strategies, and thus further research is required to investigate the use of individually tailored recovery strategies for athletes.

A known limitation when statistically analysing data is the risk of type 1 errors. A type 1 error in this thesis would equate to accepting our research hypothesis when it is false (due to chance). The risk of type 1 error is increased when multiple analyses are conducted as in this thesis. To address this risk Bonferroni adjustment was used in the statistical analyses. Another limitation of this study is that the exercise bout was a simulation of team sport game/demands and not an actual game, and the fitness and ability of the participants of this study may not replicate that of contact team sport athletes. Athlete's preconceived recovery beliefs and familiarity may have also influenced the results attained, however this was not tested and therefore cannot be verified in the current study. When applying the outcomes of this study, limitations associated with the study design should be considered. As no significant differences were found at 24 and 48 hr for performance measures future research should examine recovery strategies at earlier time points after the fatiguing exercise, to identify if a difference may be observed. Limb girths could also be investigated to examine the impact of recovery on swelling and osmotic fluid shifts (Higgins et al., 2013). By examining swelling, the perceptual swelling (DALDA) differences that were found in this study could be investigated physiologically.

4.6 Conclusion

This study has identified that there are differences amongst recovery strategies for short term perceptual and performance recovery. For short term recovery, CWT elicited better perceptions of recovery, while the non-water based ACT and CONT strategies elicited better jump performance outcomes than CWI and COMB at 1 hr post. Previously identified contributing mechanisms for these findings include influences of blood flow, stiffness, hydrostatic pressure and analgesic effects. It is recommended that future research further investigate these proposed recovery mechanisms for short term recovery from single and multiple bouts of fatiguing exercise in the hope of finding an optimal recovery method that can be confidently recommended for enhanced sporting performance.

This RCT study found no effect of recovery strategy upon performance and perceptual measures at 24 and 48 hr post fatiguing exercise. This study was also unable to detect a significantly superior or detrimental recovery strategy over the 48 hr. Based on these findings, it was concluded that a second RCT be conducted that examined recovery over a shorter period of time and in a tournament situation to identify at what time point differences between recovery strategies would occur. It was also concluded that all the investigated recovery strategies should be compared due to no clear superior or detrimental recovery strategy found after a single bout. It is anticipated that this second RCT would provide a clear indication of a superior or detrimental recovery strategy for performance and perpetual recovery.

Chapter 5

Effects of Various Recovery Strategies on Repeated Simulated Small-sided Team Sport Demands

5.1 Abstract

The aim of this study was to compare five post-exercise recovery strategies (CWI, CWT, ACT, COMB and CONT) to determine which is most effective for the recovery of performance, perceptual, physiological and flexibility measures during and after repeated simulated small-sided team sport demands.

Fourteen recreationally active males undertook repeated bouts of exercise, simulating a rugby sevens tournament day followed by the above listed recovery strategies (randomised, 1 per week). Perceptual, physiological, performance and flexibility variables were measured immediately prior to, 5 min after all three exercise bouts and at 75 min after the first two exercise bouts.

Total repeated sprint time was decreased after ACT in comparison to CONT at 75 min post bout 2 and 5 min post bout 3. Relative average power was decreased after ACT at 5 min post bout 2 in comparison to CONT and after CWI at 75 min bout 2 in comparison to CONT. Muscle soreness was increased after ACT in comparison to CONT at 5 min bout 3. The combined recovery strategy decreased muscle soreness at 75 min bout 1 and 2 and prior to bout 3 in comparison to CONT.

Active recovery is not recommended due to the detrimental performance and perceptual results noted. As no recovery strategies were significantly better than CONT for performance recovery and COMB is the only superior recovery strategy in comparison to CONT for perceptual recovery, it is difficult to recommend a recovery strategy that should be used for both performance and perceptual recovery. Thus, unless already in use by athletes, no water

immersion recovery strategies are recommended in preference to CONT due to the resource-intensive (time and equipment) nature of water immersion recovery strategies.

5.2 Introduction

There are large differences in metabolic demands between a traditional rugby union game and a rugby sevens tournament. Not only are the time frames of competition different; one 80 min game in comparison to up to 9 games of 14 min over 3 days, but the distance covered and impact count is also varied between these two types of game play. Of most importance and significance to this thesis is the difference in athlete recovery time. In a rugby sevens tournament players are required to play up to three repeated games daily over 2-3 days, whereas a rugby union game is normally only played once a week. Chapter 4 reported recovery usage after a single simulated game, this chapter will now examine recovery usage during a simulated tournament day with multiple games to assess if the same recovery strategies effect performance and perceptual recovery differently in this type of game play situation.

Optimal recovery is of particular importance to athletes competing in physically demanding events repeatedly within a short time frame, such as occurs with reduced player format tournaments. Rugby sevens tournament games consist of two, 7 min halves separated by 1 min rest with teams comprising of seven players (Del Coso et al., 2013). Games are separated by approximately 3 hr (Higham, Pyne, Anson, & Eddy, 2012) and during a game players have been measured covering approximately 1580 m, consisting of 35% standing and walking and 26% jogging, with cruising, striding, high intensity running and sprinting representing 10%, 16%, 5% and 9% of game time movement respectively (Suarez-Arrones, Nunez, Portillo, & Mendez-Villanueva, 2012). With repeated game play and little recovery time, optimal use of recovery strategies is imperative for success in the qualifying pool games and for being able to advance through to the tournament finals as physically and psychologically recovered as possible.

Little research has investigated the use of recovery strategies in a ‘tournament situation’ such as the rugby sevens, with no research identified that directly compares the effectiveness of CWI, CWT, ACT, COMB and CONT strategies in a repeated game situation. Chapter 4 investigated these same recovery strategies after a single bout, with differences found between recovery strategies at 1 hr post for performance and perceptual recovery. Thus, considering rugby sevens has different demands as discussed above, it was considered important to assess these recovery strategies in the tournament situation where less recovery time is available. Over the simulated tournament day, the effects of water immersion between games will be investigated as well as the effect of a moving recovery (ACT). Of special interest is whether CWI and COMB will induce the same stiffness and reduced power measures short term as was noted in Chapter 4 (1 hr post) and whether CWT will be more beneficial than ACT and CONT for short term perceptual recovery as it was in Chapter 4 (1 hr post).

Over a 3 day basketball tournament, Montgomery and colleagues (2008) found that repeated bouts of CWI provided an analgesic effect and assisted with decreasing muscle damage markers and performance maintenance in comparison to carbohydrates and STR and full leg compression garments. Rowsell and colleagues (2009) found over a 4-day soccer tournament that CWI did not improve performance or muscle damage markers, but did improve perceptions of soreness in comparison to thermoneutral water immersion. In contrast, Rowsell and colleagues (2011) found CWI to improve total running distance, leg soreness and fatigue/recovery in comparison to thermoneutral water immersion during a 4-day soccer tournament. The current literature indicates the need for more research particularly into the comparison of CWI, CWT, ACT and COMB usage during a single day tournament setting, such as the first day of a multi-day rugby sevens tournament. While research remains largely inconclusive, there is emerging evidence that different water-based recovery strategies may provide performance and perceptual benefits following a single bout of fatiguing exercise (Brophy-Williams et al., 2011; Delextrat et al., 2012; Duffield, Murphy, Kellett, & Reid, 2014; Elias et al., 2012, Pointon & Duffield, 2012) in comparison to passive rest and therefore it would be beneficial to examine the effectiveness of these recovery strategies across repeated exercise bouts.

The purpose of this study is to investigate the effects of five recovery methods (CWI, CWT, ACT, COMB and CONT) on indicators of performance, flexibility, physiological and perceptual recovery throughout a simulated small-sided team sport tournament day. Based on previous research (Rowsell et al., 2009; Rowsell et al., 2011), it is hypothesised that the water immersion recovery strategies would be more effective than ACT and CONT for performance and perceptual recovery variables. It is thought that the ACT recovery over the simulated tournament day may induce too much fatigue and soreness to be beneficial to repeated sport situations for performance and perceptual recovery. Whereas, over a repeated game day the water immersions may induce analgesia and improve perceptual recovery and consequent performance.

5.3 Methods

Fourteen recreationally active, uninjured, apparently healthy males voluntarily participated in the study (age: *M* = 26, *SD* = 6 years; height: *M* = 180, *SD* = 5 cm; weight: *M* = 81, *SD* = 9 kg; predicted $\dot{V}O_2max$: *M* = 41, *SD* = 3 ml/kg/min) and completed all sessions. Sample size estimation was conducted *a priori* using G* Power (Version.3.1.9.2). These calculations indicated a sample size of 24 was required (power = 0.8; p = 0.05; effect size = 0.25). Although with 40 hr of testing required per participant, authors knew that 24 participants would be very difficult to attain and retain. After almost a year of recruiting and testing it was decided to conclude testing with 14 participants that finished all 5 weeks of testing. All participants that were a part of the study conducted in Chapter 4 were invited to undertake the study. Other recruitment was via word of mouth and multimedia advertising including flyers, emails, newspaper and social media. Participants were not from a particular sport or team. All participants were able to complete the simulated bout in the second familiarisation session in the correct time (+/-5%) and were able to maintain the correct treadmill speeds on the testing days, participated in regular aerobic exercise such as recreational running and basketball and were not elite athletes. Contact sport athletes were excluded from the study if they were participating in contact sport during the testing period, due to the confounding potential for muscle soreness caused by these sports. Participants were instructed to abstain from exercise and alcohol 24 hr, food 2 hr and caffeine 4 hr prior to sessions.

Additional variables have been included in this study compared to Chapter 4. The sleep diaries and Karolinska sleepiness scale have been included as the study in Chapter 4 raised issues around sleep; specifically whether participants were attaining the same amount and quality of sleep the night before testing and how alert they felt on the day of testing. Water intake was also addressed, due to concerns it may have impacted upon participant efforts and results in Chapter 4. Blood lactate was included to investigate the research suggesting that water immersion strategies and ACT may assist with blood lactate clearance (Dunne et al., 2013; Ferreira et al., 2011; Hudson et al., 1999; Martin et al., 1999; Parouty et al., 2010; Pointon & Duffield, 2012). Yo-yo intermittent recovery tests were also utilized as a further measure to assess fatigue of the participants. And lastly swelling was assessed by girth measurements and the DALDA scale category of swelling were included as suggested in Section 4.6.

Sleep diaries were completed throughout the testing period (Sargent, Halson, & Roach, 2014). Participants recorded the number of hours slept the night before testing (Sargent et al., 2014) and also rated their daytime sleepiness according to the Karolinska sleepiness scale (Shahid, Wilkinson, Marcu, & Shapiro, 2012) before going to bed and upon rising. Exercise diaries were completed throughout the testing period and were analysed to confirm consistency of exercise throughout the testing period and adherence to the research project instructions. Participants were informed of the procedures to be undertaken, as well as the benefits and risks of the investigation prior to signing a consent form approved by the Human Ethics Committee of James Cook University. Ethics approval was granted by the Human Ethics Committee of James Cook University H5969 (Appendix H).

Participants performed two familiarisation sessions as per Section 4.3, with the addition of the Karolinska sleepiness scale (Shahid et al., 2012) and sleep quality scale (Robey et al., 2014), and instead of the multi-stage fitness test, the yo-yo intermittent recovery test level 1 (Bangsbo, Iaia, & Krustrup, 2008) was completed to predict $\dot{V}O_2max$. Practice of the exercise bout and familiarisation with the same scales and recovery strategies occurred as per Section 4.3 with the inclusion of. The yo-yo intermittent recovery test has a test-retest coefficient variation of 4.9% (Krustrup et al., 2003) and a significant correlation to $\dot{V}O_2max$ (correlation factor of $r = .70$; Bangsbo et al., 2008), and to high-intensity running, sprinting, high-speed running and total distance covered in a soccer match (correlation range $r = .53 - .71$; Krustrup et al., 2003), which is why it was used as a team sport specific fatiguing exercise and indicator of participant fatigue throughout the testing day. Although it needs to be acknowledged that the simulated matches in this protocol were not the length of a soccer match and the yo-yo test's application to this research has been assumed.

The data collection throughout the testing day was based on the timings of a rugby sevens tournament day, with 3 hr between each of the three simulated rugby sevens bouts

(Higham et al., 2012). The data collection times were as follows: immediately before bout 1 (B1pre), 5 min after bout 1 (B1post5), 75 min after bout 1 (B1Post75), immediately before bout 2 (B2pre), 5 min after bout 2 (B2post5), 75 min after bout 2 (B2post75), immediately before bout 3 (B3pre) and 5 min after bout 3 (B3post5). Figure 5.1 shows the variables and timings of the testing day. The session took approximately 8 hr to complete, and was repeated at approximately one week intervals until all five recovery strategies had been completed in random order. Participants were provided with the same types and amount of food across all five testing sessions. Participants performed testing at approximately the same time each day.

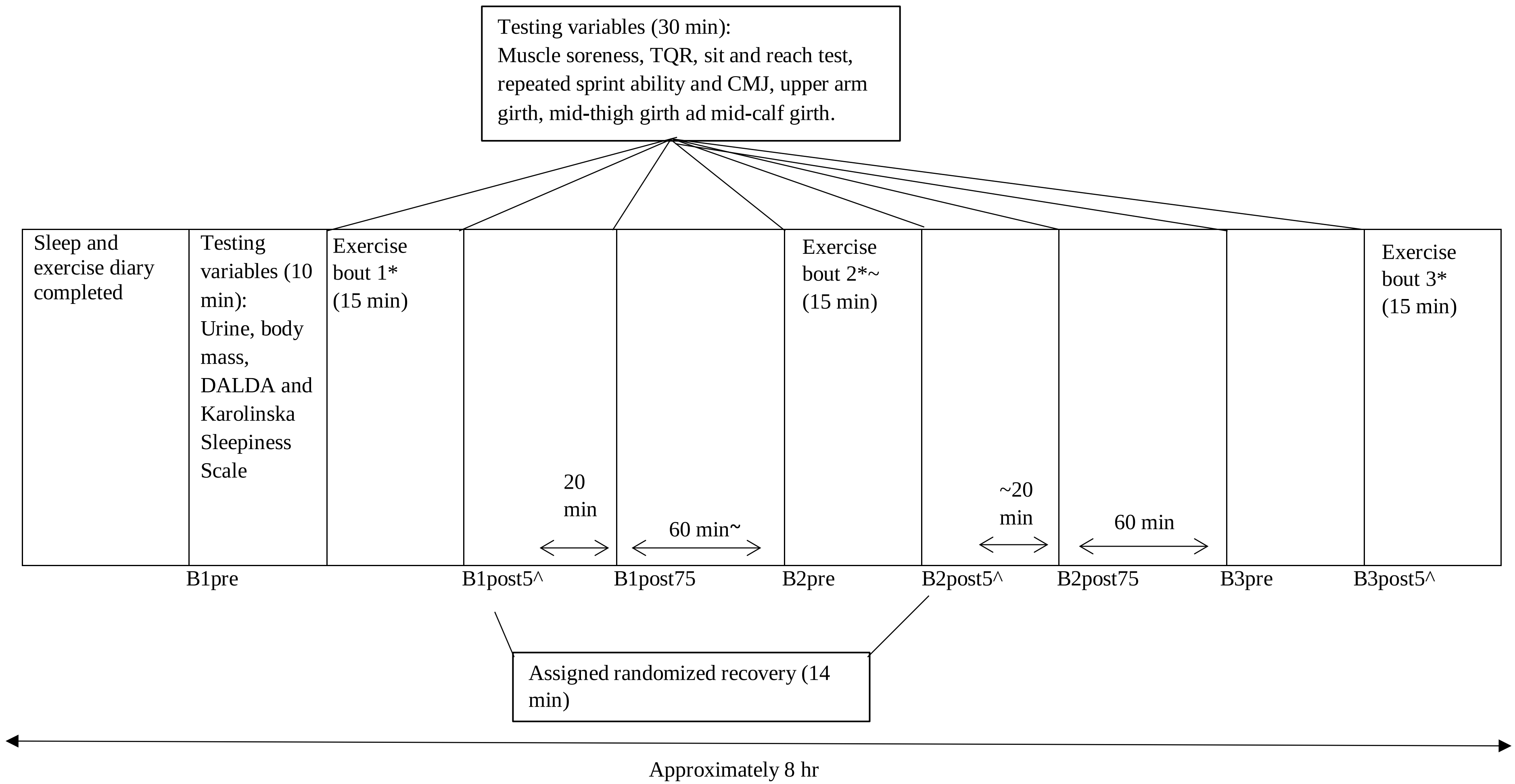

Figure 5.1. Schematic diagram of the variables and timings of the testing day

*HR recorded throughout and RPE at conclusion, ^Yo-yo intermittent recovery test undertaken, ~Lactate sample taken, DALDA- daily analysis of life demands for athletes, TQR- total quality recovery, CMJ- countermovement jump, 5PostB1- 5 min post bout 1, 75PostB1- 75 min post bout 1, PreB2- pre bout 2, 5PostB2- 5 min post bout 2, 75PostB2- 75 min post bout 2, PreB3- pre bout 3, 5PostB3- 5 min post bout 3

Upon arrival for testing participants provided a urine sample that was assessed for hydration status via urine specific gravity measurement with the use of a handheld refractometer (John Morris Scientific Pty Limited, Japan), and body mass was measured (Tanita, BC-545N, Japan) for subsequent power calculations for the CMJ test.

The participants also completed the DALDA questionnaire (Rushall, 1990), muscle soreness scale (Pointon & Duffield, 2012) and TQR scale (Kenttä & Hassmén, 1998), as described in Section 4.3, along with the Karolinska sleepiness scale and sleep quality scale. The Karolinska sleepiness scale was a 10 point scale that ranged from 1 (extremely alert) to 10 (extremely sleepy, can't keep awake; Shahid et al., 2012; Appendix I). The sleep quality scale was a five point scale that ranged from 1 (very good) to 5 (very poor; Robey et al., 2014; Appendix J). Mid-calf girth was measured at the maximum segmental girth of the calf (French et al., 2008), mid-thigh girth was taken with the participant standing, at the mid-point between the trochanter and the lateral epicondyle of the femur (adapted from French et al., 2008) and the upper arm girth was taken at the mid-point between the superior and most lateral aspect of the acromion and the proximal, lateral border of the head of the radius (International Standards for Anthropometric Assessment, 2001). The same investigator measured girths at each testing session. Girths were marked with a pen, so the girths could be measured at the same landmark throughout the day, but required re-measurement at the commencement of each test day. The participant's water bottle was weighed upon arrival and throughout the day to monitor water intake.

The standardised, generalised warm up was undertaken prior to completion of the sit and reach, repeated sprint ability and the CMJ tests. The sit and reach test was performed three times, with the best measurement recorded for analysis. Participants undertook the repeated sprint ability test (Elias et al., 2012; Elias et al., 2013), and CMJ (Elias et al., 2012; King & Duffield, 2009) as described in Section 4.3.

After testing for performance and perceptual measures participants commenced the first of three bouts of exercise with 3 hr between each. Each exercise bout was 15 min in duration and was designed to simulate the demands of a rugby sevens game. This simulated game exercise bout included 2 x 7 min halves, with a 1 min half time rest (in this time participants were allowed to consume water, walk, stand or sit close to the start area). The activities performed in each half were identical and consisted of four repetitions of the same circuit (Figure 5.2 below). Each circuit involved a set combination of the six different speeds and proportional amount of time spent at each speed (seconds rounded in-text), that was reported by Suarez-Arrones and colleagues (2012) following time motion analysis of a rugby sevens tournament; standing time ranged from approximately 1-7 sec (total time 16.5 sec), walking 20 sec (total time 20 sec), jogging 1.5-16 sec (total time 27.5 sec), cruising 0.5-8 sec (total time 10.5 sec), striding 0.7-13 sec (total time 15.7 sec), high intensity running 0.5-4 sec (total time 5.3 sec), and sprinting 9 sec (total time 9 sec; Figure 5.2). Each participant had their own individualised circuit measured out such that the proportional time spent at each movement intensity was the same for all participants, but the distance covered by each participant was altered in accordance with their individual max running speed. Percentages of max speed were calculated using the max speed recorded in the first familiarisation session max sprints. A tackle bag was taken to ground each circuit repetition after the first high intensity run, to add in a contact component to further simulate the rugby sevens physical demands (Singh et al., 2010), the number of tackles to be undertaken was determined from rugby sevens time motion analysis research (Suarez-Arrones et al., 2014). The jogging, cruising and striding activities were performed on a motorised treadmill (Trackmaster TMX22, United States of America) set to the pre-determined speed for each participant, and the high intensity running and sprinting speeds were performed on a measured grassed area due to the treadmill belt speed restrictions. Participants were signalled when to begin each running sequence and were prompted to ensure that the required running speed was achieved. Standing and walking was interspersed throughout the circuit in proportions noted to occur during the rugby sevens games (Suarez-Arrones et al., 2012). Heart rate (Polar Electro Oy, Finland) was recorded once each circuit before beginning the first high intensity run and Borg's RPE (Borg, 1982) was recorded at the completion of the 15 min exercise bout. The mean inter-assay coefficient of variation for RPE and average HR across all first simulated bouts over the five sessions was 10% and 3% respectively, showing high reproducibility of the test conditions and participant effort. All exercise bouts were timed as confirmation that the protocol had been adhered to (+5%).

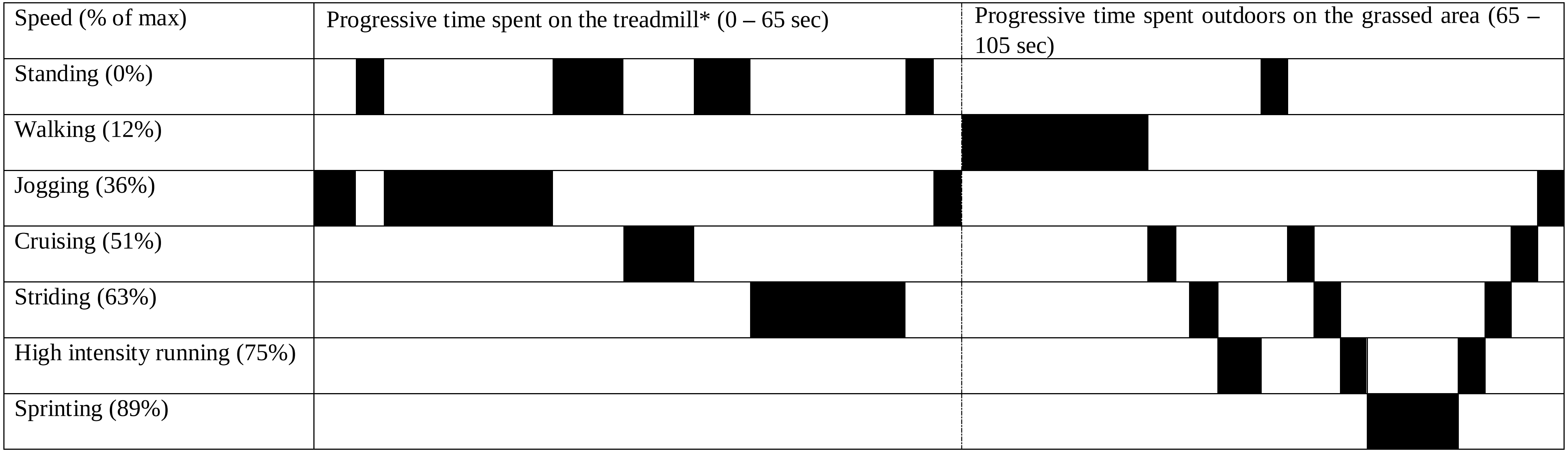

Figure 5.2. Movement patterns per circuit (adapted from Suarez-Arrones et al., 2012).

Not to exact scale. *The first and last portion of jogging was performed on the floor while transitioning to and from the treadmill from outside.

Following a 5 min rest after completing the first exercise bout, participants had their mid-calf, mid-thigh and upper-arm girth measurements recorded, and completed the TQR and muscle soreness scale. Sit and reach, repeated sprint ability, CMJ and the yo-yo intermittent recovery test were then performed (B1post5). The yo-yo intermittent recovery test level 1 was used to assess fatigue of the participants, as it has been shown to be an intermittent test which replicates the intermittent nature of team sport, along with using both aerobic and anaerobic energy systems as would be used in a rugby sevens game (Krustrup et al., 2003). Another 5 min rest was then given before participants completed a 5 min jog at 35% peak speed (adapted from King & Duffield, 2009) on the treadmill. This jog was implemented for practical reasons, as many teams would undertake an active warm down prior to undertaking a specific recovery. Participants then undertook their randomly assigned recovery protocol, CWI, CWT, ACT, COMB or CONT as described in Section 4.3, except the ACT protocol which included jogging/fast walking on the treadmill at 35% peak speed as adapted from King and Duffield (2009; the speed was reduced if participants felt that the recovery was strenuous). Participants' heart rate was recorded every 10 sec during the COMB protocol and averaged 50% (6%) of their maximum heart rate during this recovery, confirming the low intensity nature of the activity. All recovery protocols and testing procedures were performed at natural environmental temperatures with no significant difference found over the five sessions for temperature (p = .655; average range over five conditions 24.3 °C - 25.8 °C) and humidity (p = .263; average range over five conditions 56.7% - 61.0%).

After the recovery protocol, participants undertook seated rest for 75 min from the completion of exercise. Participants then had their mid-calf, mid-thigh and upper-arm girth measurements taken, completed the TQR and muscle soreness scale, performed the standardised warm up, and completed the sit and reach, repeated sprint ability and CMJ tests (B1post75). Participants then undertook seated rest (approximately 60 min) until 150 min had lapsed since completion of the first exercise bout. During this time participants were given standardised food;

either a banana or an apple. Participants were allowed to drink as much water as they desired throughout the day, with all water consumption measured and recorded.

At 150 min after the first exercise bout (B2pre), participants completed the same measurements as B1post75, which took approximately 25 min to complete, with the addition of a finger prick blood lactate sample (Lactate Pro analyser, Arkray, Japan) at 4 min before the commencement of the second exercise bout (B2pre4). Three hr after the first bout had been completed participants commenced the second exercise bout. The exercise bout, follow-up measurements (B2post5 and B2post75) and rest procedures for the second exercise bout were the same as those of the first exercise bout with the addition of a blood lactate measurement 4 mins after the completion of the second bout (B2pre4) and 4 min after the completion of recovery (B2post4recovery). During the rest between B2post75 and B3pre, the participants were given standardised food, either a sandwich or wrap consisting of meat and salad. At 150 min after the completion of the second exercise bout (B3pre), participants repeated the same measurements as B2pre (with the exclusion of blood lactate), then at 3 hr post exercise bout 2 participants completed the third and final exercise bout. The third exercise bout and the measurements taken at B3post5 were the same as B2post5 (with the exclusion of blood lactate collection). No further testing occurred following B3post5.

At the conclusion of all testing participants were asked which recovery strategy they thought was most effective and which was least effective and to give reasons why. Participants were blinded to the results of the performance, flexibility and physiological tests.

5.3.1 Statistical analyses

Data were analysed using the Statistical Package for Social Sciences (IBM SPSS Incorporation, Version 22, Chicago, Ill, USA) via two-way (time x recovery) repeated measures ANOVA and *post hoc* Tukey HSD tests. Data were presented as means, (*SD*) with alpha set at .05. Minimum detectable change (MDC) was also calculated for both group recovery and interaction results and individual interaction participant change (Silva et al., 2015) for performance and perceptual results. The interaction MDCs and the % of individual participant interactions that exceeded the MDC are included in text and Table 5.1. All results are interaction results unless specified. P-values are presented for significant main effects. For performance and perceptual variables tables 5.2-5.5 present all of the significant interaction and main time effects. For the performance and perceptual results only significant between recovery differences, main recovery effects, main time effects and respective recovery differences from baseline (interaction) are noted. For the other measures only main recovery effects, main time effects and interaction results that are of practical importance are noted in text. The following variables were analysed; hr slept night before testing, Karolinska sleepiness scale, sleep quality, DALDA scale, hydration, water intake, TQR, muscle soreness, total repeated sprint time, relative (normalised for mass) average and best jump power performances, blood lactate concentration, mid-calf girth, mid-thigh girth, upper-arm girth, best sit and reach performance, HR, bout completion time, RPE and yo-yo intermittent recovery test scores (test scores were converted from levels to ascending numbers (ordinal data) for analyses). The following recovery related components of the DALDA scale were analysed (letter responses were converted to ordinal numbers for analysis): muscle pains, need for rest, recovery time, unexplained aches, between session recovery and swelling. Incomplete data points were estimated by using the recovery and time specific average (below 1% of data).

5.4 Results

No significant differences were found between testing sessions for hours of sleep before testing (p = .064), sleepiness rating on the night before (p = .316), on the morning of (p = .387) and immediately before testing (p = .228); or for sleep quality (p = .402). There were also no significant differences between test sessions for DALDA scale ratings, for hydration (p = .823), or for the volume of water consumed during the test sessions (p = .983).

No interaction or recovery strategy group minimum detectable changes were indicated for total sprint time, relative average and best power, TQR, muscle soreness, blood lactate, sit and reach, HR, completion time of each bout, RPE and yo-yo intermittent recovery test score. The percentage of individual participant interactions (ranging from 7-21%) that exceeded the interaction MDC and most common findings are in Table 5.1. The common findings show ACT was detrimental to all measures and CWT improved all measures except bout completion time.

Table 5.1

Participant minimum detectable change results

Variable	Interaction MDC value	% of individual participant interactions that MDC is exceeded	Most common results in comparison to CONT
Total repeated sprint time	2.6	13	ACT mostly detrimental
Relative average CMJ power	1.6	16	CWT mostly improved and ACT mostly detrimental
Relative best CMJ power	1.7	13	CWT mostly improved and ACT mostly detrimental
Total quality recovery	4.4	9	CWI mostly improved
Muscle soreness	2.8	21	COMB mostly improved and ACT mostly detrimental
Blood lactate	6.9	7	ACT and COMB detrimental
Sit and reach flexibility	4.7	13	CWI, CWT and COMB mostly improved and ACT mostly detrimental
Average HR bout 1 half 1	11.1	14	CWI, CWT and COMB mostly decreased
Completion time of bout 1 half 1	5.8	14	All recovery strategies mostly increased time of completion
RPE	3.7	9	ACT half improved and half detrimental
Yo-yo intermittent recovery test	5.3	13	CWI and ACT mostly detrimental

Note. CMJ = countermovement jump; HR = heart rate; RPE= rating of perceived exertion; MDC = minimum detectable change; CONT = control; ACT = active recovery; CWT = contrast water immersion; COMB = combined recovery; CWI = cold water immersion

At B2post75 and B3post5 CONT, CWT and COMB (B3post5 only) produced significantly faster sprint times than ACT (Table 5.2). At B2post5 and for the remainder of the day CWI and ACT total sprint times were significantly slower in comparison to baseline (Table 5.2). For each individual recovery B3post5 sprint times were significantly slower than baseline (Table 5.2). There was a main effect for total sprint time with a progressive increase over the day (excluding B2pre) in comparison to baseline (22.3 sec; B1post5 23.1 sec, p = .002, B1post75 23.0 sec, p = .003, B2post5 23.8 sec, p = .003, B2post75 24.0 sec, p < .001, B3pre 24.1 sec, p = .004 and B3post5 24.8 sec, p < .001; Table 5.2).

Table 5.2

Total repeated sprint time assessed at baseline, 5 min after and 75 min after (excluding bout 3) three bouts of simulated intermittent activity for each of the different recovery strategies.

	M (*SD*)				
Time	Control (CONT)	Cold (CWI)	Contrast (CWT)	Active (ACT)	Combined (COMB)
B1pre (baseline)	22.0 (1.3)	22.4 (1.9)	22.5 (1.6)	22.0 (1.6)	22.3 (1.4)
B1post5[f-h]	23.0 (1.7)	23.1 (2.1)[a]	23.1 (1.5)	23.0 (2.0)[a-c]	23.1 (1.8)
B1post75[f-i]	22.1 (1.2)[a]	23.5 (2.0)	22.8 (1.6)	23.3 (2.2)[a-c]	23.1 (1.6)
B2pre[hij]	22.3 (1.6)[a]	23.2 (2.2)	22.8 (1.5)	23.5 (2.6)[ab]	23.0 (1.7)
B2post5[f]	23.2 (1.8)	24.0 (2.5)[d]	23.6 (1.5)	24.5 (2.7)[ad]	23.6 (1.9)
B2post75[f]	23.1 (1.3)[e]	24.4 (2.6)[d]	23.2 (1.5)[e]	25.4 (3.2)[d]	23.9 (1.8)[d]
B3pre[f]	23.5 (2.0)	24.3 (2.3)[d]	23.8 (2.2)	25.0 (3.5)[d]	23.6 (1.5)
B3post5[f]	24.1 (1.8)[de]	24.8 (2.8)[d]	24.2 (2.2)[de]	26.2 (3.2)[d]	24.5 (1.9)[de]

Note. Interaction effects: [a]Significant difference to B3post5 at the respective time. [b]Significant difference to B2post75 at the respective time. [c]Significant difference to B3pre at the respective time. [d]Significant difference in comparison to B1pre at the respective time. [e]Significant difference to ACT at the respective time. Main time effects: [f]Significant difference in comparison to B1pre. [g]Significant difference to B2post75. [h]Significant difference to B3post5. [i]Significant difference to B3pre. [j]Significant difference to B2post5.

Average and best power after ACT were significantly less at B2post5 in comparison to CONT (not relative best) and COMB (Table 5.3). At B2post75 and B3post5 ACT average power was significantly less than CWT; while at B2post75 CWI average power was significantly less than CONT and CWT (Table 5.3). Power measures were significantly decreased after CWI and ACT at B2post5 and for the remainder of the day (not at B3pre after ACT for relative best) in comparison to baseline (Table 5.3). All recovery strategies had decreased power measures at B3post5 (except relative best after COMB) in comparison to baseline (Table 5.3). A main effect for time was found for relative average power and relative best power, with power higher at baseline (relative average power 15.8 W/kg, relative best power 16.4 W/kg) in comparison to B1post5 (relative average power 15.2 W/kg, $p < .001$, relative best power 15.7 W/kg, $p < .001$), B1post75 (relative average power 15.3 W/kg, $p = .006$), B2post5 (relative average power 15.0 W/kg, $p = .003$, relative best power 15.7 W/kg, $p = .004$), B2post75 (relative average power 15.0 W/kg, $p = .011$, relative best power 15.6 W/kg, $p = .010$), B3pre (relative best power 15.7 W/kg, $p = .045$) and B3post5 (relative average power 14.7 W/kg, $p = .011$, relative best power 15.4 W/kg, $p = .010$; Table 5.3).

Table 5.3

Relative average and best CMJ power assessed at baseline, 5 min after and 75 min after (excluding bout 3) three bouts of simulated intermittent activity for each of the different recovery strategies.

	M (*SD*)				
Measures	Control (CONT)	Cold (CWI)	Contrast (CWT)	Active (ACT)	Combined (COMB)
Relative average CMJ power (W/kg)					
B1pre (baseline)	15.9 (2.0)	16.1 (2.5)	15.7 (2.0)	15.5 (2.1)	15.8 (2.1)
B1post5[g]	15.2 (2.3)[a]	15.4 (2.5)[ab]	15.1 (2.1)	15.0 (2.2)[c]	15.2 (2.0)
B1post75[g]	15.7 (2.1)[c]	15.1 (2.7)[a]	15.3 (2.2)	15.2 (2.3)[c]	15.2 (1.9)
B2pre[h]	15.6 (2.3)	15.5 (2.6)[bc]	15.4 (1.8)	15.1 (2.1)[c]	15.5 (2.0)
B2post5[g]	15.2 (2.2)[d]	15.1 (3.0)[a]	15.2 (1.8)	14.5 (2.2)[a]	15.3 (2.0)[d]
B2post75[g]	15.3 (2.2)[e]	14.5 (2.2)[a]	15.4 (2.1)[de]	14.7 (2.1)[a]	14.9 (2.2)[a]
B3pre	15.4 (2.4)	15.1 (2.0)[a]	15.1 (1.9)	14.8 (2.2)[a]	15.1 (2.3)
B3post5[g]	14.9 (2.4)[a]	14.7 (2.0)[a]	14.9 (2.0)[ad]	14.2 (1.9)[a]	14.9 (2.3)[a]
Relative best CMJ power (W/kg)					
B1pre (baseline)	16.5 (2.1)	16.8 (2.5)	16.5 (2.0)	16.2 (2.0)	16.3 (2.1)
B1post5[g]	15.7 (2.3)[a]	16.0 (2.7)	15.6 (2.1)[a]	15.6 (2.2)	15.7 (2.0)
B1post75	16.4 (2.1)[c]	15.7 (2.7)[a]	16.0 (2.4)	15.9 (2.2)[cf]	15.8 (1.8)
B2pre[h]	16.2 (2.1)[c]	16.1 (2.6)[b]	16.1 (1.8)	15.8 (2.1)	16.1 (2.0)
B2post5[g]	15.8 (2.3)	15.6 (2.2)[a]	15.8 (1.8)	15.1 (2.2)[a]	16.0 (2.0)[d]
B2post75[g]	15.9 (2.3)	15.3 (2.2)[a]	15.9 (2.1)	15.3 (1.9)[a]	15.5 (2.1)
B3pre[g]	16.0 (2.4)	15.7 (2.0)[a]	15.7 (1.9)	15.5 (2.1)	15.6 (2.3)
B3post5[g]	15.4 (2.6)[a]	15.4 (2.0)[a]	15.5 (2.0)[a]	15.0 (1.8)[a]	15.5 (2.4)

Note. Interaction effects: [a]Significant difference in comparison to B1pre at the respective time. [b]Significant difference to B2post75 at the respective time. [c]Significant difference to B3post5 at the respective time. [d]Significant difference to ACT at the respective time. [e]Significant difference to CWI at the respective time. [f]Significant difference to B2post5 at the respective time. Main time effects: [g]Significant difference in comparison to B1pre. [h]Significant difference to B2post75.

During the ACT recovery, TQR was significantly reduced for the entire day in comparison to baseline, and was significantly reduced in comparison to COMB at B2pre and CWI, CWT and

COMB at B2post75 and B3pre (Table 5.4). For all individual recovery strategies TQR was significantly reduced from baseline at B1post5 and at B2post5 and for the remainder of the day (excluding CWT at B2post75; Table 5.4). Total quality recovery demonstrated a significant main effect for time, with TQR significantly reduced from baseline (15.8) at B2post5 (11.9, p = .014) and for the rest of the testing day (B2post75 13.0, p = .041, B3pre 12.6, p = .016 and B3post5 11.0, p = .005; Table 5.4).

Table 5.4

Total quality recovery assessed at baseline, 5 min after and 75 min after (excluding bout 3) three bouts of simulated intermittent activity for each of the different recovery strategies.

	M (*SD*)				
Time	Control (CONT)	Cold (CWI)	Contrast (CWT)	Active (ACT)	Combined (COMB)
B1pre (baseline)	15.8 (3.8)	16.1 (2.8)	15.7 (3.3)	15.4 (3.0)	16.1 (2.6)
B1post5[h]	12.6 (2.3)[ab]	13.1 (1.3)[ab]	12.5 (2.2)[ac]	13.1 (2.4)[abde]	13.1 (1.7)[ab]
B1post75[h-k]	14.3 (1.6)[b]	14.3 (2.5)[bd]	15.1 (1.9)[bde]	13.4 (2.4)[abdef]	14.5 (1.8)[b]
B2pre[h-k]	14.2 (1.6)[b]	14.3 (2.4)[bd]	14.0 (1.6)[bd]	12.9 (2.6)[abd]	14.8 (1.7)[bdg]
B2post5[hl]	12.5 (1.3)[a]	11.6 (2.2)[a]	12.0 (2.0)[a]	10.9 (2.3)[a]	12.7 (1.7)[a]
B2post75[hil]	12.7 (1.9)[ab]	13.4 (2.2)[abg]	14.0 (2.0)[bdg]	11.4 (2.5)[a]	13.6 (2.1)[abg]
B3pre[hl]	12.4 (1.8)[a]	13.1 (2.3)[abg]	13.1 (2.4)[ag]	11.0 (2.6)[a]	13.3 (2.3)[abg]
B3post5[l]	10.7 (2.4)[a]	11.1 (2.4)[a]	11.7 (2.0)[a]	10.2 (2.7)[a]	11.1 (2.2)[a]

Note. Interaction effects: [a]Significant difference in comparison to respective B1pre. [b]Significant difference to respective B3post5. [c]Significant difference to respective B1post75.[d]Significant difference to respective B2post5. [e]Significant difference to respective B3pre. [f]Significant difference to respective B2post75. [g]Significant difference to ACT at the respective time. Main time effects: [h]Significant difference to B3post5. [i]Significant difference to B2post5. [j]Significant difference to B2post75. [k]Significant difference to B3pre. [l]Significant difference to B1pre.

Muscle soreness demonstrated a significant main effect for recovery strategy, with COMB (3.5) found to have significantly decreased soreness scores in comparison to ACT (5.0, p = .017).

Combined recovery resulted in significantly less muscle soreness at B1post75 in comparison to CONT, CWI and ACT, at B2pre in comparison to CWI and ACT, at B2post5 and B3post5 in comparison to ACT, at B2post75 and B3pre in comparison to CONT and ACT (Table 5.5). At B1post75 and for the remainder of the day ACT resulted in greater muscle soreness than COMB, at B2post75 and B3pre ACT resulted in significantly greater muscle soreness than CWI and CWT; while at B3post5 ACT resulted in significantly greater muscle soreness than CONT and CWT (Table 5.5) Muscle soreness during CONT, CWI and ACT were significantly increased at all time points during the day in comparison to baseline (Table 5.5). Contrast water therapy and COMB increased muscle soreness significantly in comparison to baseline at B1post5 (not COMB), at B2post5 and for the remainder of the day (Table 5.5). A main effect for time was found with muscle soreness significantly increased over the day (except B1post75) in comparison to baseline (1.8; B1post5 3.5, p = .010, B2pre 3.6, p = .008, B2post5 5.0, p = .001, B2post75 4.9, p = .002, B3pre 5.4, p = .001, and B3post5 5.4, p = .001; Table 5.5).

Table 5.5

Muscle soreness assessed at baseline, 5 min after and 75 min after (excluding bout 3) three bouts of simulated intermittent activity for each of the different recovery strategies.

	M (*SD*)				
Time	Control (CONT)	Cold (CWI)	Contrast (CWT)	Active (ACT)	Combined (COMB)
B1pre (baseline)	2.0 (2.4)	1.5 (1.6)	2.2 (2.2)	1.9 (2.1)	1.6 (1.6)
B1post5[h-l]	3.6 (1.9)[a-e]	3.8 (1.7)[ade]	3.6 (1.9)[ae]	3.5 (1.5)[a-e]	2.8 (1.5)[bde]
B1post75[i-l]	3.3 (1.9)[a-f]	3.3 (1.9)[a-f]	2.8 (1.5)[b-e]	3.9 (1.6)[a-e]	1.9 (1.1)[b-eg]
B2pre[h-l]	3.8 (1.8)[a-e]	4.0 (1.9)[ad-f]	3.3 (1.6)[bde]	4.3 (1.6)[a-e]	2.7 (1.2)[bdeg]
B2post5[hl]	5.1 (2.0)[a]	4.7 (1.9)[ae]	4.8 (1.4)[a]	5.9 (1.6)[ae]	4.5 (1.4)[aeg]
B2post75[hl]	5.2 (2.7)[af]	4.9 (2.1)[aeg]	4.4 (1.6)[aeg]	6.2 (1.5)[ae]	3.9 (1.8)[aeg]
B3pre[hl]	5.8 (2.8)[af]	5.3 (2.3)[ag]	4.8 (1.7)[ag]	6.6 (1.6)[a]	4.5 (2.2)[aeg]
B3post5[h]	6.2 (2.6)[ag]	6.3 (2.2)[a]	6.0 (1.8)[ag]	7.5 (2.0)[a]	6.1 (1.9)[ag]

Note. Interaction effects: [a]Significant difference in comparison to respective B1pre. [b]Significant difference to respective B2post5. [c]Significant difference to respective B2post75. [d]Significant difference to respective B3pre. [e]Significant difference to respective B3post5. [f]Significant difference to COMB at the respective time. [g]Significant difference to ACT at the respective time. Main time effects: [h]Significant difference to B1pre. [i]Significant difference to B2post5. [j]Significant difference to B2post75. [k]Significant difference to B3pre. [l]Significant difference to B3post5.

Contrast water therapy, ACT and COMB resulted in significantly higher blood lactate concentrations at B2post4 compared to B2pre4 (not CWT) and B2post4recovery (Figure 5.3). Control and CWI did not show any changes in lactate concentration over the testing period (Figure 5.3). A main effect for time for blood lactate concentration was found, with bout 2 demonstrating higher values (5.4 mmol/L) than B2pre4 (2.6 mmol/L, $p < .001$) and B2post4recovery (2.3 mmol/L, $p < .001$).

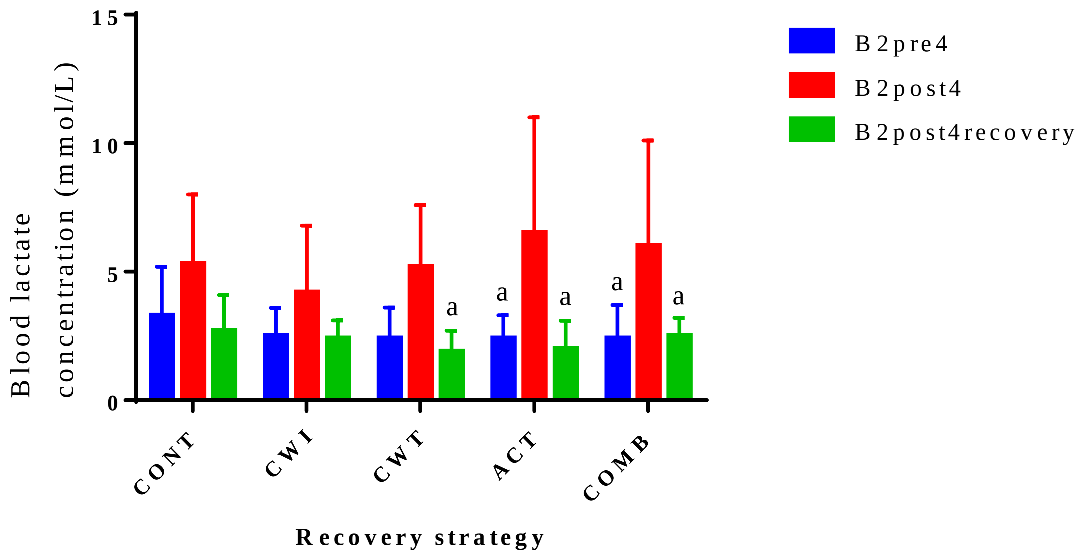

Figure 5.3. Blood lactate concentration measured at B2pre4, B2post4 and B2post4recovery for each of the different recovery strategies.

a Significantly different to respective B2post4

Control showed no significant differences for mid-calf girth over the day (Figure 5.4). For CWI, mid-calf girth was larger at B1post5 in comparison to B1post75, B2pre, B2post75 and B3pre; and larger at B2post5 and B3post5 in comparison to B2post75 (Figure 5.4). For CWT, mid-calf girth was larger at B1post5 compared to B1post75 and B2post75; and B2post5 was larger than B1post75 (Figure 5.4). For ACT, mid-calf girth was larger after B1post5 in comparison to B2pre, B2post75, B3pre, B3post5; and B1post75 was larger than B3pre (Figure 5.4). For COMB, mid-calf girth at B1pre was larger than B1post75 and B2post75; B1post5 was larger than B1post75, B2pre, B2post75, B3pre and B3post5; and B2post5 was larger than B1post75 and B2post75 (Figure 5.4). A main effect for time was found for mid-calf girth with B1post5 (38.2 cm) significantly larger than B1post75 (37.8 cm, $p < .001$), B2pre (37.9 cm, $p = .008$), B2post75 (37.7 cm, $p < .001$), B3pre (37.8 cm, $p = .010$)

and B3post5 (37.9 cm, p = .025); B2post5 (38.1 cm) was also significantly larger than B1post75 (p = .048) and B2post75 (p = .005).

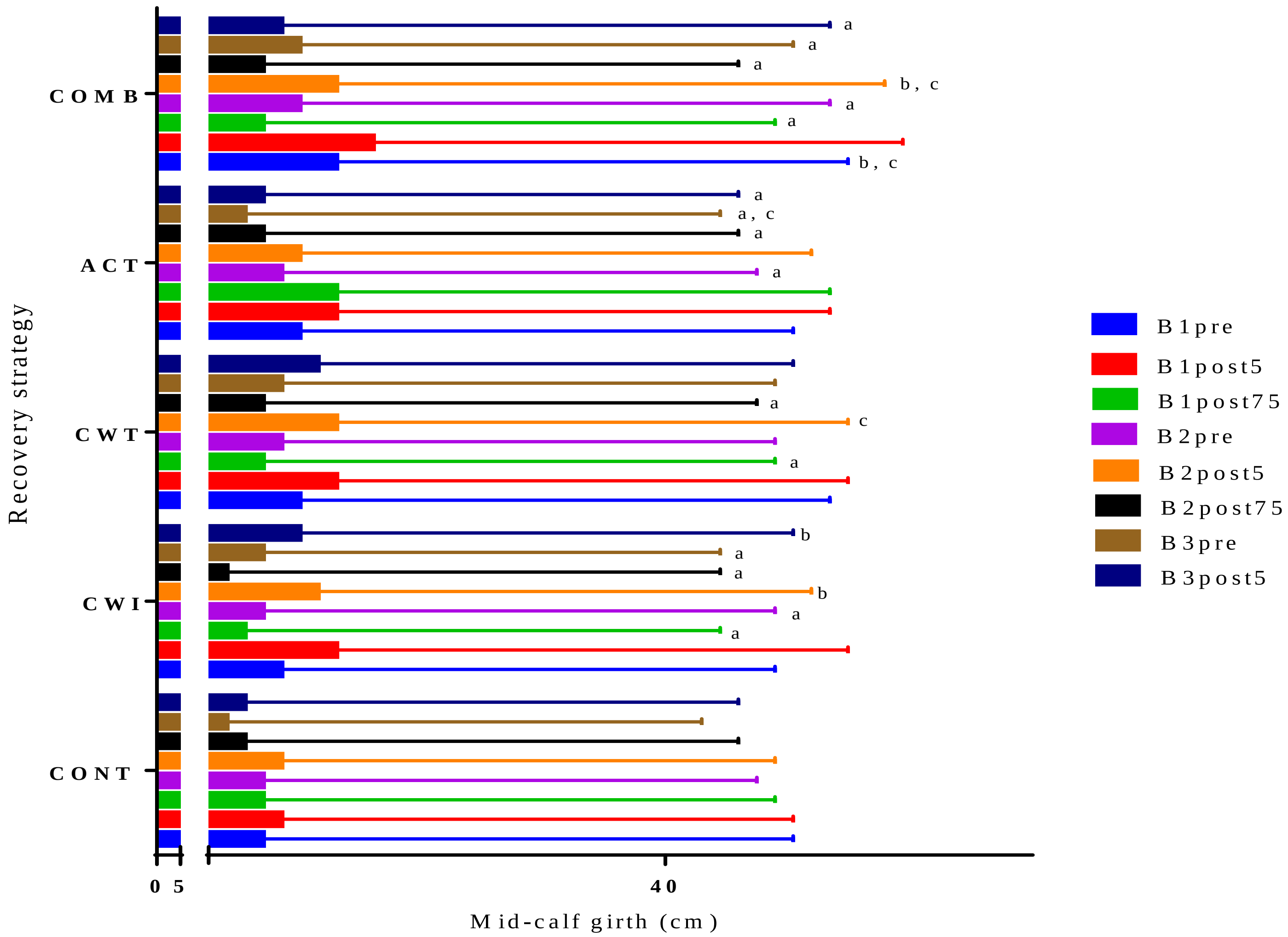

Figure 5.4. Mid-calf girth measured at baseline, immediately after and 75 min after three bouts (not bout 3) of fatiguing exercise for each of the different recovery strategies.

a Significantly different to respective B1post5; b Significantly different to respective B2post75; c Significantly different to respective B1post75.

A main effect for time was found for mid-thigh girth, with B3pre (55.4 cm) significantly smaller than B3post5 (55.6 cm, p = .029). No within recovery significant differences were found for mid-thigh and upper-arm girths. Between recovery differences and interaction effects were not analysed for girths, due to the likelihood that day-to-day measurement error may have occurred.

At B3post5 ACT best sit and reach (27 cm) was significantly lower than after CWT (29 cm) and COMB (30 cm). A main time effect occurred for best sit and reach, with B1post75 (28 cm) significantly less than at B2pre (29 cm, p = .015). Average HR was significantly changed over the course of the three bouts, with average HR significantly higher in the second half of each bout (bout 1 half 2 163 bpm, bout 2 half 2 166 bpm and bout 3 half 2 166 bpm) in comparison to the respective first half (bout 1 half 1 156 bpm, p < .001, bout 2 half 1 159 bpm, p < .001, bout 3 half 1 160 bpm, p < .001) but no differences were found between recovery strategies. Simulated bout 3 half 1 took significantly longer to complete after ACT (7 min 13.9 sec) compared to CWT (7 min 10.9 sec) and COMB (7 min 10.7 sec). A main effect for time for completion time of each half was identified, with bout 3 half 1 (7 min 11.9 sec) taking significantly longer to complete than all other bouts and halves (bout 1 half 1 7 min 8.9 sec, p = .003, bout 1 half 2 7 min 9.6 sec, p = .019, bout 2 half 1 7 min 9.4 sec, p = .001, bout 2 half 2 7 min 10.0 sec p = .007 and bout 3 half 2 7 min 9.9 sec, p = .010). No between recovery differences were found for RPE. A main effect for time for RPE indicated a lower rating after bout 1 (15) in comparison to after bout 2 (16, p = .005) and bout 3 (17, p = .001); bout 2 was also significantly smaller than bout 3 (p = .028). No between recovery differences were identified for yo-yo intermittent recovery test scores. A main effect for time for yo-yo intermittent recovery test scores was found, with pre testing yo-yo intermittent recovery test scores (14.5) found to be significantly higher than after bout 2 (10.2, p = .049) and 3 (9.4, p = .023). Bout 1 (12.5) was also significantly higher than after bout 2 (p = .009) and 3 (p = .012).

At the conclusion of all protocols, CWT was rated as the most effective recovery strategy by the most participants (50% of responses), with the most common reasons being 'refreshing' and 'feelings of an increase in energy'. Participants rated ACT the least effective recovery strategy (57% of responses) for reasons such as 'did not provide rest' and 'increased fatigue', followed by CWI (29% of responses), with the most common response 'too cold'.

5.5 Discussion

This study identified CWT to be the most effective recovery strategy for performance recovery (in comparison to ACT, but not CONT). The COMB recovery strategy was superior for perceptual recovery in comparison to ACT and CONT. The ACT recovery was detrimental to total sprint time and relative average power at B2post75 and B3post5 in comparison to CWT and CONT (not relative average power). Total quality recovery was also significantly reduced after ACT at B2pre and for the remainder of the day (excluding B2post5 and B3post5) and muscle soreness at B1post75 and for the remainder of the day in comparison to COMB.

This study found performance (total sprint time and CMJ), perceptual measures of recovery (total quality recovery and muscle soreness) and yo-yo intermittent recovery scores to deteriorate over the testing day. Furthermore, RPE and bout completion time also increased over the day, indicating the need for a recovery that minimises the effects of fatigue, and that the protocols were fatiguing enough to induce performance and perceptual decrements.

Contrast water therapy was found to be the optimal recovery strategy and ACT suboptimal for performance (total sprint time and relative average power) maintenance across the day and for sit and reach flexibility (at B3post5). Active recovery was also found to increase bout 3 half 1 completion time in comparison to CWT and COMB. Contrast water therapy has been shown in previous research to maintain performance from the initial fatiguing exercise bout in comparison to CONT over times ranging from 35 min (Crampton et al., 2011) to 2 hr (Versey et al., 2011), 24 and 48 hr (Vaile et al., 2007); and in comparison to ACT (Crampton et al., 2013) at 40 min post fatiguing exercise. Vaile and colleagues (2007) reason that CWT may be effective for performance maintenance due to four reasons; firstly, that increased hydrostatic pressure causes muscular and vascular compression and hence less swelling, which this study has shown CWT to reduce swelling with significantly smaller mid-calf girths at B1post75 and B2post75 in comparison to B1post5. Secondly, the hot component of CWT may increase vasodilation which increases the supply of oxygen to the muscles (Vaile et al., 2007). Thirdly, the CWI component of CWT decreases skin temperature which causes an increase in sympathetic drive causing a shift in blood from the limbs (Vaile et al., 2007). Lastly, the transitions from CWI (vasoconstriction) to hot water (vasodilation) may cause movement of blood flow in the muscles, which may lead to attenuation of the immune response (Vaile et al., 2007) and decreased muscle damage. Active recovery was found to be detrimental to relative average power, bout 3 half 1 completion time and sit and reach flexibility, this may be due to the extra metres covered by participants (between 4 and 5 km over the day) and the expected resultant soreness and fatigue and potential limited glycogen resynthesis (Barnett et al., 2006; Choi et al., 1994).

The COMB recovery strategy was found to be most effective and ACT to be least effective for alleviating perceptions of fatigue across and between the repeated bouts of simulated small-sided games. A number of studies support the positive perceptual findings of a COMB recovery strategy (Hudson et al., 1999; Kinugasa & Kilding, 2009). Suggested reasons explaining why a COMB protocol is more effective in preventing decreased perceptual recovery than CWT, CWI, ACT and CONT include movements of the lower limb causing an oscillating shift in blood volume (Hudson et al., 1999), which may assist with increased blood flow and accordingly enhanced perceptual benefits. Furthermore, CWI and COMB recovery strategies may cause a decrease in experienced pain by a reduction in neuron transmission speed within the body (Meeusen & Lievens, 1986). This might explain the prevalent analgesic effects reported for CWI strategies (Jakeman et al., 2009), and may assist in the alleviation of some sensations associated with tiredness and improve performance. Post-exercise cooling strategies such as COMB may reduce intramuscular temperature and provide a means to restore homeostasis (Myrer, et al., 1998) and hence increase feelings of recovery. Active recovery was unable to prevent a significant increase in perceived soreness and reduced feelings of recovery. Active recovery was also found to have significantly increased muscle soreness and decreased TQR at all time points in comparison to baseline and to be significantly worse than COMB and other recovery strategies at a number of time points. Hudson and colleagues (1999) also found COMB to have improved perceptions of recovery in comparison to ACT. During ACT participants are moving and expending energy; so it is likely they do not feel recovered from this form of recovery. Participants' rated ACT as the worst recovery strategy and their comments of 'did not rest' and 'felt fatiguing' support their negative perceptions of this type of recovery. The larger distances travelled by participants during the ACT recovery strategy may have also contributed to the feelings of tiredness.

This study has shown that mid-calf girth increased after exercise in comparison to baseline. This is expected due to the increase in muscle oedema following exercise. Interestingly, for ACT the mid-calf girth at B1post75 is the same as B1post5, showing the recovery has not reduced the swelling in the muscle. This study has also found that TQR, total sprint time and power measures were restored B2pre, after all recovery strategies. This demonstrates and supports other research that shows there is still inconclusive evidence for the use of one recovery strategy over another for recovery after one bout of exercise (Parouty et al., 2010; Rowsell et al., 2009; Stanley et al., 2014).

The measurement of girths and blood lactates are limitations of this study. With no means of assuring measurement at the exact same point on the body each session, girths were incomparable across recovery strategies, despite the use of standardised measurement techniques. Blood lactate was measured at a restricted number of time points and therefore did not provide comprehensive blood lactate profiling across the testing day. Another limitation is the additional workload imposed by the performance tests undertaken throughout the testing day, which may have potentially impacted upon performance and perceptual recovery. The fitness and ability of the participants of this study is also a potential limitation, as it may not replicate that of a rugby sevens team. Another limitation as previously discussed is the risk of Type 1 error. Bonferroni adjustment has been undertaken in the statistical analyses to reduce this risk. The last limitation is the testing of variables across repeated bouts of simulated rugby sevens performance, not at a rugby sevens event. When applying the outcomes of this study, limitations associated with the study design should be considered.

When interpreting the significant *p* value interaction effects, it is important to consider whether these effects are supported by MDCs; and whether the differences are practically (or clinically) meaningful in applied sporting context. At B2post75 CWT improved average power in comparison to ACT ($p < 0.05$) by 0.7 W/kg and CWI ($p < 0.05$) by 0.9 W/kg. While these group mean changes are less than that needed for a minimum detectable change (1.6 W/kg difference), this difference equates to an approximate difference of 5%, which in a repeated game situation would be likely to have meaningful impact. For muscle soreness at B2post75 COMB decreased soreness by 1 point on the scale in comparison to CONT ($p < 0.05$); at the same time ACT increased soreness in comparison to CWI ($p < 0.05$) by 1 point, CWT and COMB ($p < 0.05$) by 2 points. While the group mean changes were not large enough to indicate minimum detectable change (2.8), this difference in a repeated game setting would still assist athletes perceptually and likely allow for better game play throughout the day. At B3post5 ACT total sprint time was larger than all other recovery strategies (p < 0.05); CONT by 2.1 sec, CWI by 1.4 sec, CWT by 2 sec and COMB 1.7 sec. These differences although not large enough to be identified as a minimal detectable change (2.6 sec), would still very likely have a meaningful impact and would potentially allow an athlete to beat an opposing player to the ball/try line.

Of note as in Chapter 4 while no significant MDCs were evident for group interaction or recovery data, across all variables between 9-21% of individual participant interactions exceeded the relevant MDC (Table 5.1). Overall, the common findings from the individual participant results indicated that ACT was detrimental to all variables in comparison to CONT, which supports the group findings of this Chapter; although not all individual results aligned with the findings of this

Chapter. This Chapter again indicates that athletes appear to have very individualised responses to recovery strategies, and thus further research is required to investigate the use of individually tailored recovery strategies for athletes. It is also recommended that future research investigate the use of CWI, CWT, ACT and COMB on performance, perceptual, physiological and flexibility measures at a rugby sevens or small-sided game tournament over multiple days, with the inclusion of added lactate analysis time points. The hypothesis of this study was partially fulfilled, with CWT and COMB found to be more effective than ACT for performance and perceptual recovery respectively for a large number of time points, although water immersion strategies were most of the time found to be no better than CONT for performance and perceptual recovery.

5.6 Conclusion

This study has identified that there are differences amongst recovery strategies for perceptual and performance recovery over a simulated rugby sevens tournament day. Active recovery was found to be a suboptimal recovery strategy for both perceptual and performance recovery in a small-sided tournament game setting and thus is not recommended for use in a tournament situation. This study adds new knowledge to recovery research where currently little information exists in tournament settings.

The identification of recovery usage by team sport athletes and their perceptions and reasons for use have led to the coaching recommendations and conclusions detailed in the next Chapter of this thesis. The performance and perceptual results from the RCTs have also provided coaching recommendations and conclusions on the effectiveness of popular recovery strategies.

Chapter 6

General Discussion

6.1 Summary of Contrast Water Therapy Findings

Overall, the effect of CWT is unclear with no differences compared to CONT for performance after a single bout or during a simulated tournament day. Contrast water therapy is preferable to ACT over the full tournament day for performance, with improvements induced from 4 hr onwards. For perceptual recovery at 1 hr post CWT was better than CONT after a single bout but no differences were found over a simulated tournament day in comparison to CONT.

It is not known why CWT was neither perceptually effective over the simulated tournament day nor effective for performance after a single bout of exercise, although the different fatiguing exercises may have contributed to these findings and require further investigation. Contrast water therapy may be effective for consistent performance maintenance in comparison to ACT due to already discussed detrimental mechanisms of ACT such as increased energy use and no rest combined with the addition of some positive mechanisms associated with CWT. One such proposed positive CWT mechanism is hydrostatic pressure which increases cardiac output and reduces peripheral resistance, which may enable exercise-induced substrates such as lactate to be transported away from the muscles more quickly. Hydrostatic pressure may also improve perceptions of recovery due to the buoyancy of the body, reduced neurotransmitter activity and oedema. As discussed earlier the cold component of CWT may also contribute to recovery by inducing peripheral vasoconstriction, which increases venous return, stroke volume, and cardiac output as well as reducing the potential for oedema. Cold water immersion may also assist with perceptions of recovery due to the induced analgesia.

The hot component of CWT has the opposing effect of the CWI, it will increase vasodilation, which increases circulation (Cochrane, 2004) and the supply of oxygen to the muscles (Vaile et al., 2007). The transitions from CWI (vasoconstriction) to hot water (vasodilation) may also cause movement of blood flow in the muscles, which may lead to attenuation of the immune response and reduce myocellular damage (Vaile et al., 2007). Contrast water therapy may also cause movement of blood from the extremities due to a decrease in skin temperature and up-regulated sympathetic activity when alternating from hot to cold (Vaile, et al., 2007). Contrast water therapy was superior to CONT and ACT for perceptual recovery 1 hr post a single bout and at the conclusion of both RCTs participants rated it as the most effective recovery strategy. Both the current survey findings (used for mainly psychological purposes) and previous literature (Kovacs & Baker, 2014) attribute this to the heat-induced relaxing and therapeutic effect on the body. As discussed earlier this may also be due to athletes' preconceived beliefs about CWT and/or their familiarity or comfort with this recovery strategy.

6.2 Summary of Cold Water Immersion Findings

The results of this thesis also bring the high anecdotal use of CWI and COMB (as supported by national and international athlete survey responses) into question for single and repeated game team sport athletes, with CWI and COMB having no consistent positive effect upon performance after a single bout of exercise or during a simulated tournament day in comparison to CONT. The combined recovery strategy did not improve perceptual recovery after a single bout of exercise, but did consistently improve perceptual recovery in comparison to CONT and ACT during the simulated tournament day.

Performance was decreased by CWI and COMB 1 hr post a single bout which is likely due to insufficient time for the muscles to rewarm, although a brief warm up had been undertaken also. Crowe and colleagues (2007) reasoned that cold water may cause peripheral vasoconstriction and less blood flow to major muscle groups which combined with insufficient time for muscles to rewarm, could have contributed to the decreased power performance at 1 hr.

A factor which may have influenced CWI perceptions of the surveyed athletes is team bonding, as the surveyed athletes were team sport athletes they may have performed CWI as a team, and viewed it as more enjoyable/beneficial than athletes undertaking this strategy individually as in the RCTs. These findings may also be different due to the recovery duration used, as CWI was mostly used for 10 min by surveyed athletes in comparison to the CWI protocol used after the RCTs which had a duration of 14 min (Chapter 4 and 5). The lack of beneficial effects of CWI after a single bout of fatiguing exercise and repeated bouts is in contrast to studies that have shown CWI to be effective over a time frame that ranges from 25 min – 24 hr post fatiguing exercise in comparison to CONT for performance (Brophy-Williams et al., 2011; Crampton et al., 2013; Dunne et al., 2013; Delextrat et al., 2012) and over a time frame that ranges from 1 – 48 hr post fatiguing exercise in comparison to CONT for perceptual (Brophy-Williams et al., 2011; Elias et al., 2012; King & Duffield, 2009; Stacey et al., 2010) recovery. It is not known why these results contrast those of this thesis, except that the varying CWI protocols in these studies are not the same as used in this thesis.

Both the current survey findings (AWB) and published studies support the positive perceptual findings of a COMB recovery (Kinugasa & Kilding, 2009; Hudson et al., 1999). A suggested reason for the effectiveness of COMB in preventing reduced perceptions of recovery is a decrease in experienced pain by a cold-induced reduction in neuron transmission speed within the body (Meeusen & Lievens, 1986). Water movement may also induce a higher cooling rate of the body due to the continuous movement of cold water around the body; while the movement of the limbs in the COMB recovery strategy may increase muscle temperature. These aspects of the recovery strategy may increase feelings of recovery. Water immersion buoyancy may also reduce fatigue by reducing the gravitational forces on the body (Wilcock et al., 2006). This results in partial relaxation of gravitational muscles (Wilcock et al., 2006), potentially enhancing perceptual recovery after COMB. The physiological changes as a result of a COMB recovery needs further investigation.

6.3 Summary of Active Recovery Findings

Overall, the findings of this thesis indicate that an ACT recovery is not of practical use during a tournament day for the purpose of augmenting performance or perceptual recovery. Despite this, after a single bout of exercise, ACT improved performance at 1 hr in comparison to CWI and COMB while interestingly decreased perceptual recovery at the same time in comparison to CWT. During ACT recovery, participants were moving (in Chapter 5 this equated to 4-5 km of additional activity across the day) and potentially expending energy; core temperature and metabolism may have also remained raised. Further, ACT has been found to reduce glycogen resynthesis, likely due to the reliance on these glycogen stores as energy to complete the recovery (Choi et al., 1994). Active recovery is also weight bearing which may cause more fatigue and decreased recovery perceptions than a passive, seated recovery and may not give athletes the feeling of 'recovery' they are seeking post-exercise. Interestingly, at 1 hr after a single bout of fatiguing exercise, ACT was found to produce significantly better jump performance than CWI and COMB. This contrasted the results of the systematic review which indicated that ACT was detrimental to the performance of a submaximal exhaustive cycling bout 40 min post this same exercise (Crampton et al., 2013), this may be due to the 30 min duration of the ACT recovery in the Crampton and colleagues (2013) study, inducing potentially fatigue and soreness in the participants and causing a decrement in subsequent performance. Active recovery is difficult to compare due to different intensities and durations performed.

6.4 Summary of Overall Findings

The results of this thesis indicate that no one recovery strategy of those investigated demonstrated a meaningful contribution to recovery in the context investigated. There were elements within each recovery strategy which could be construed as useful, but there was no sufficiently consistent positive effect compared with a control condition. Much of the application of a recovery strategy is based on anecdotal evidence or subjective feelings about whether it is effective. The use of body cooling (and warming) for example is of perceptual benefit to recovery shortly after exercise but this is likely to be more due to sensations of redressing core body temperature and relaxation after undertaking vigorous work. It is experimentally challenging to show such sensations impacting in a meaningful way to post-exercise performances over a 1-2 day period when this is most likely a highly personalised process. Data do not appear to conclusively support the use of any one recovery strategy over another, but perhaps the question ought to be whether the athlete perceives their recovery process to be supported by a particular recovery strategy. In instances where the athlete has not been hindered by the recovery strategy it may be adequate that they are able to choose one recovery strategy from a list of options and further research may support and contextualise the use of personalised recovery strategies.

Chapter 2 systematic review articles that investigated water immersion and ACT after a single and repeated bout of exercise are of limited to moderate methodological quality, with most studies not meeting the criteria of adequate data collection. The results of this thesis indicate that the majority of surveyed team sport athletes utilise one or more recovery strategies, fulfilling the hypothesis that the majority of athletes would undertake some form of recovery strategy. All levels of athlete utilised STR the most (excluding international), partially fulfilling the hypothesis that STR would be most used by all levels of athlete. Stretching was rated the most effective recovery strategy, with ALB considered the least effective, not supporting the hypothesis that water immersion would be considered the most effective. Laziness and time constraints were the main self-reported reasons provided for not undertaking a structured post-exercise recovery routine, this is most likely due to the large percentage of athletes that were of a local or regional level of competition (68%). The water immersion strategies were considered either effective or ineffective mainly due to psychological reasons; in contrast STR and ALB were considered to be effective or ineffective mainly due to physical reasons. In the context of short term recovery from a single bout of fatiguing exercise, such as following a competition game, CWT was found to be most effective for perceptual recovery, with CWI and COMB found to be least effective and ACT and CONT to be most effective for recovery of leg power (Chapter 4), only partially supporting the hypothesis that water immersion and ACT strategies would be superior to CONT for performance and perceptual recovery after a single bout of fatiguing exercise. During a simulated small-sided game tournament day, CWT was found to be most effective for performance recovery in comparison to ACT only and COMB to be most effective for perceptual recovery, with ACT noted to be least effective for performance and perceptual recovery (Chapter 5). These findings partially support the hypothesis that water immersion strategies would be superior to CONT and ACT for performance and perceptual recovery during a simulated tournament day. This thesis attempts to explain the proposed mechanisms of different recovery strategies, although they are theoretical in nature and have not been directly measured and warrant further investigation due to the complex nature between mechanisms.

The results of the current RCTs add new findings to the literature with the investigation of the COMB recovery strategy, which was shown to be effective for perceptual recovery across a simulated small-sided game tournament day. In summary, this thesis has found (Chapters 3-5) no particular recovery strategy is optimal for small-sided game tournament performance, and ACT and CONT are recommended for short term performance recovery. For perceptual recovery a CWT recovery is recommended for short-term recovery after a single exercise bout and a COMB recovery for use during a small-sided game tournament day.

6.5 Recommended Sport Applications

The results of this thesis can provide coaching staff and athletes of various sports and competition levels with further high quality information on recovery strategy selections (Table 6.1 and 6.2). The following recommendations and Tables 6.1 and 6.2 are based on the results of Chapters 4 and 5 where there was a statistical difference between the specific recovery strategy and CONT. When no particular recovery strategy is recommended is when there was no statistical difference between the recovery strategy and CONT, and therefore any recovery strategy could be chosen. These results as discussed in Section 6.6 have their limitations and need to be considered when applying these results to practical settings. For athletes that have played a game of 1 hr duration and have an hour before their next game, such as club level athletes competing in two divisions/grades on a single competition day, an ACT recovery of 14 min on a grassed area or track performed at 35% of peak speed or CONT recovery for performance is recommended, noting that the ACT recovery strategy may cause suboptimal perceptions of recovery and therefore is not recommended if the aim is to enhance perceptual recovery. For these same athletes, CWT is recommended for perceptual recovery, and this may include sitting with shoulders immersed in thermoregulated swimming pools or temperature controlled portable pools for 7 cycles of 1 min in 15 ºC and 1 min in 38 ºC (shoulder immersion) or 7 cycles of alternation between 1 min hot and 1 min cold showers. For these same athletes CWI of 14 min of 15 ºC shoulder immersion and COMB 14 min of 15 ºC shoulder immersion with leg movement are specifically not recommended for performance. For athletes that compete in one game and have one training session per week, with both sessions more than 48 hr apart, such as local team sport athletes; or athletes that compete in two games per week and train every other day, such as elite basketball players; there is no particular recovery strategy that can be recommended or specifically not recommended for performance or perceptual recovery from the synthesis of the current RCT findings. For athletes that compete in one game per week and train twice a day on some days throughout the week such as elite rugby league players; or for players competing in 2-3 reduced-duration games per day such as rugby sevens tournament players, no one particular recovery strategy is recommended for performance For perceptual recovery for the same athletes a COMB recovery strategy is recommended that includes 14 min of 15 ºC shoulder-height seated immersion with flexion-extension movement of the legs in a thermoregulated swimming pool or portable pool, or walking on a submerged treadmill or walking/jogging in the ocean or at a local pool. An ACT recovery of 14 min performed at 35% peak speed is specifically not recommended for performance or perceptual recovery for these types of athletes.

Table 6.1

Recovery strategy recommendations for performance recovery

Team sport scenario	Options for recommended recovery strategies	Recovery strategies that are specifically not recommended
One hour between games (e.g. local competition athletes playing across different grades in one day).	ACT	CWI and COMB.
One game and one training session per week, >48 hr apart (e.g. local team sport athletes).	No particular recovery strategy recommended.	No particular recovery strategy is specifically not recommended.
Two games per week and training every other day (e.g. elite basketball players).	No particular recovery strategy recommended.	No particular recovery strategy is specifically not recommended.
One game per week and training twice a day on some days each week (e.g. elite rugby league players).	No one particular recovery strategy recommended.	ACT
2-3 reduced-duration games per day (e.g. rugby sevens tournament players).	No one particular recovery strategy recommended.	ACT

Note. ACT= active recovery – 14 min performed at 35% peak speed; CWI = Cold water immersion – 14 min of 15 ºC shoulder immersion; COMB = combined – 14 min of 15 ºC shoulder immersion with leg movement.

Table 6.2

Recovery strategy recommendations for perceptual recovery

Team sport scenario	Options for recommended recovery strategies	Recovery strategies that are specifically not recommended
One hour between games (e.g. local competition athletes playing across different grades in one day).	CWT	ACT
One game and one training session per week, >48 hr apart (e.g. local team sport athletes).	No particular recovery strategy recommended.	No particular recovery strategy is specifically not recommended.
Two games per week and training every other day (e.g. elite basketball players).	No particular recovery strategy recommended.	No particular recovery strategy is specifically not recommended.
One game per week and training twice a day on some days each week (e.g. elite rugby league players).	COMB	ACT
2-3 reduced-duration games per day (e.g. rugby sevens tournament players).	COMB	ACT

Note. CWT = contrast water therapy – use of thermoregulated pools or temperature controlled pools for 7 cycles of 1 min in 15 ºC and 1 min in 38ºC (shoulder immersion) or 7 cycles of alternation between 1 min hot and 1 min cold showers; ACT= active recovery – 14 min performed at 35% peak speed; COMB = combined – 14 min of 15 ºC shoulder immersion with leg movement.

6.6 Strengths and Limitations

This thesis has a number of strengths in the unique and applicable findings that have been presented. Firstly, the extensive survey utilised was based on published research and was able to capture a large number of athletes of different competition levels and sports (331 athletes, 5 competition levels, 14 team sports). Secondly, Both RCT fatiguing exercise protocols were based on published team-sport research. A large number of variables to investigate performance, perceptual and physiological indices of recovery were also used in these RCTs. Thirdly, the RCTs were controlled and investigated the use of four recovery strategies that are anecdotally used, along with the inclusion of a COMB recovery strategy protocol which has not been previously directly and simultaneously compared to CWI, CWT, ACT or CONT. The unique protocols of this thesis have been able to provide practical recommendations to athletes and coaches.

Although this thesis has a number of strengths it also has a number of limitations that need to be considered when reviewing the results presented in this thesis. Firstly, the statistically significant results found in this thesis may not always equate to meaningful differences when these numbers are considered in a practical sports science context. For example, a statistically significant difference between perceptual ratings may only mean a difference of 0.3 (Chapter 3), which does not correlate to an actual difference on a 1-5 perceptual scale. As alluded to in Chapters 4 and 5 although a number of group (*p* values) and individual (MDC) changes were found, the nature of the changes did not always align with the findings of this thesis, thus the findings need to be applied with caution as recovery responses appear to be somewhat individualised. The systematic review results were difficult to synthesise due to the variation of fatiguing exercise protocols, recovery protocols, testing variables, time points and statistical analyses. The survey was undertaken by team sport athletes mostly in northern Australia, thus the results may not be indicative of the entire country. The RCTs were conducted using simulated team sport games and demands, not actual and specific competition or tournament games. The large number of variable testing time points (eight) during the simulated tournament day may have negatively impacted upon performance and perceptual fatigue. Furthermore, the variable testing during this tournament day and after a single bout of fatiguing exercise does not replicate and is not specific to what would happen in team sport competition or tournaments, but was necessary to assess performance, perceptual and physiological recovery of athletes. Further, the variables assessed did not evaluate the mechanisms of the recovery strategies, including muscle temperature assessment. The smaller sample size (N = 14) that participated in the second RCT is also a limitation, although it was very difficult to attract and retain a large number of participants when they were required to commit to 40 hr of research testing. The difference between sample groups of the RCTs is a further limitation, although four participants were the same for both trials and the participant characteristics were very similar. The survey participants were mainly of local or regional level and thus the results from the survey are less applicable to higher level athletes. The lower level of fitness of the participants in Chapters 4 and 5 is also a limitation. It is recommended that future research investigate the effects of recovery upon muscular temperature, particularly whether a COMB recovery induces increased muscle temperature in comparison to other water immersion recovery strategies. Athlete's preconceived recovery beliefs may have also influenced the results attained. Lastly, the four participants that participated in both RCTs may have started the second RCT with preconceived beliefs from their experiences with the first RCT.

6.7 Future Research

The results presented in this thesis have significantly contributed to research in the area of recovery, and new questions for future research have been proposed. Firstly, it is recommended that more research be conducted that is of a higher methodological quality. It is also recommended that the use of and mechanisms associated with popular post-exercise recovery strategies including massage and the use of mental techniques (Keilani et al., 2016) within Australia (coverage of multiple states and cities) and their reasons for use continue to be investigated. Future research could also investigate the use of the five recovery strategies (CWI, CWT, ACT, COMB and CONT) after an actual competition game and also throughout a multiple-day tournament. Another question raised from these studies is whether team sport athletes require individualised recovery strategies for optimum results, as participants responded to recovery strategies differently and a number of individual participant interactions that were of clinical significance were identified. It is very likely and the findings of this thesis support that no single recovery will work optimally for every athlete in a team when recovery effectiveness is assessed against a combination of perceptual, performance and physiological outcomes. This may correlate with the majority of research that shows there is no conclusive evidence regarding the most effective recovery strategy for team performance and perceptual recovery. The interaction between an athlete's perception of their recovery and their physical ability to reproduce high quality, maximal exercise is a complex relationship. Edwards and Polman (2013) indicate that the brain regulates exercise performance via relative awareness of one's limitations. Thus, it is suggested that the ability to perform exercise may be decreased due to sensations of incomplete recovery. Further, these thesis results indicate that perceptual recovery does not always align with performance recovery. It is recommended that more research be undertaken to investigate the effects of perceptions, recovery comfort, familiarity and the placebo effect of particular recovery strategies on performance recovery and their relationship, and which, if either is more important to the coach and athlete. This thesis attempts to explain the proposed mechanisms of different recovery strategies, although they are theoretical in nature and have not been directly measured and warrant further investigation due to the complex nature between mechanisms. Future research should investigate specifically biochemical and physiological mechanisms associated with recovery; for example how long the muscles take to rewarm after cold water immersion strategies; and how does muscle temperature change during the COMB recovery strategy.

6.8 Conclusion

The studies presented in this thesis provide insight into the reasons why Australian athletes use recovery and that athlete understanding of the recovery mechanisms do not always coincide with the scientific evidence. Thus, it is recommended that updated advice be provided to athletes and coaches so that they can make more informed decisions about using various recovery strategies. Based on the results from this thesis the following advice is recommended:

- Contrast water therapy is recommended to be used for short term (1 hr) perceptual recovery after a team sport game.
- A combined recovery (of CWI and ACT) should be elected for superior perceptual recovery throughout a team sport tournament day.
- Cold water immersion and a COMB recovery (of CWI and ACT) should not be used for short term (1 hr) performance recovery, for example in short breaks between games.
- An active recovery should not be used for performance and perceptual recovery throughout a team sport tournament day.
- Further investigation into the potential individualisation of recovery as well as the mismatch of performance and perceptual recovery is needed.

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Appendices

Appendix A: Chapter 2 Systematic Review Results Tables

Table A.1

CWI vs CONT for anaerobic performance

Included studies: Argus et al., 2016; Acensao et al., 2011; Bailey et al., 2007; Broatch et al., 2014; Cengiz et al., 2016; Cook & Beaven, 2013; Corbett et al., 2012; Crowe et al., 2007; Delextrat et al., Elias et al., 2013; Elias et al., 2012; Fonseca et al., 2016; Garcia et al., 2016; Getto et al., 2013; Jakeman et al., 2009; King & Duffield, 2009; Parouty et al., 2010; Pointon & Duffield, 2012; Pournot et al., 2011; Rowsell et al., 2014; Schniepp et al., 2002; Sellwood et al., 2007; Stacey et al., 2010; Stanley et al., 2014; Stanley et al., 2012; Takeda et al., 2014; White et al., 2014; Yeung et al., 2016.

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Muscle strength variables (amplitude, duration, latency, MVC, voluntary activation, root mean square, peak torque, time to peak twitch torque, work, fatigue rate, half-relation time, contraction duration, rate of torque development and rate of relaxation)	Immediately post recovery (13), 5 min, 10 min (3), within 30 min, 1 hr (3), 2 hr (13), 4 hr, 24 hr (18), 48 hr (5), 72 hr (2), 96 hr and 168 hr (2) post.	No difference at immediately post (5), 5 min, 10 min (3), within 30 min, 1 hr (3), 2 hr (13), 4 hr, 24 hr (17), 48 hr (4), 72 hr (2), 96 hr and 168 hr (2) post. Improved immediately post recovery (8), 24 hr and 48 hr post.
Jump variables (power, velocity, flight time: contraction time, flight time and height)	Immediately, 5 min (2), 20 min (2), within 30 min (2), 30 min, 1 hr (9), 2 hr (10), 4 hr (2), 12 hr (2), 24 hr (23), 25 hr, 48 hr (17) and 168 hr post	No difference at immediately, 5 min (2), within 30 min (2), 1 hr (9), 2 hr (10), 4 hr (2), 12 hr, 24 hr (17 and 1 study in women only), 25 hr, 48 hr (15) and 168 hr post. Improved at 30 min, 12 hr, 24 hr (6 and 1 study in males only) and 48 hr post (2). Decreased at 20 min post (2).
Sprint variables (mean, total time, time, ideal time and decrement)	Within 30 min, 24 hr (9), 25 hr, 48 hr (4) and 168 hr post.	No differences at within 30 min, 24 hr (6), 25 hr, 48 hr (3) and 168 hr post. Improved at 24 hr (3) and 48 hr post.
Rope climb	30 min and 24 hr post	Improved at both times.
Hop test	24 hr (2), 48 hr (2), 72 hr (2) and 168 hr post.	No differences.

Cycling variables (peak power, total work, cadence, maximum power, average power, time trial and time to peak power)	15 min (3), 20 min, 30 min (2), 40 min, 1 hr (3), 3 hr 25 min and 9 hr (2) post.	No difference at 15 min, 20 min, 30 min (2), 40 min, 3 hr 25 min, 9 hr (2) post. Decreased at 15 min (2) and 1 hr (2) post.
Power	Immediately, 1 hr, 24 hr (2) and 48 hr post recovery.	No difference immediately, 1 hr, 24 hr and 48 hr post. Improved at 24 hr post.
Agility	20 min and 12 hr post	No difference at 12 hr. Decreased at 20 min post.
100m maximal swim	30 min post.	Decreased.
Reaction time	24 hr post.	No difference.
Side steps	24 hr post.	No difference.

Note. CWI = cold water immersion; CONT = control; MVC = maximum voluntary contraction

Table A.2

CWI vs CWT for anaerobic performance

Included studies: Argus et al., 2016; Elias et al., 2013; Elias et al., 2012; King & Duffield, 2009; Pournot et al., 2011; Stanley et al., 2012

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CWT at time point (number of studies 1, unless stated).
Muscle strength	5 min, 1 hr, 2 hr, 4 hr, 24 hr post.	No difference in all studies at all time points.
Jump variables (power, velocity and height, flight time: contraction time and flight time)	5 min (2), 1 hr, 2 hr (2), 4 hr (2), 24 hr (7), 25 hr and 48 hr post (5).	No difference in all studies at all time points.
Sprint variables (time, mean and total time)	24 hr (4), 25 hr and 48 hr (2) post.	No difference in all studies at all time points.
Cycling variables (time, average power)	3 hr 25 min post.	No difference in all studies at all time points.
Power	1 hr and 24 hr post.	No difference in all studies at all time points.

Note. CWI = cold water immersion; CWT = contrast water therapy

Table A.3

ACT vs CWI for anaerobic performance

Included studies: Corbett et al., 2012; King & Duffield, 2009; Stacey et al., 2010

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CWI at time point (number of studies 1, unless stated).
Sprint variables (mean and total time)	24 hr (2) and 25 hr post.	No difference in all studies at all time points.
Jump variables	24 hr and 25 hr post.	No difference in all studies at all time points.
Cycling variables (time trial)	20 min and 40 min post.	No difference in all studies at all time points.
MVC	24, 48, 72 and 168 hr post.	No difference in all studies at all time points.
Hop test	24 hr, 48 hr, 72 hr and 168 hr post.	No difference in all studies at all time points.

Note. ACT = active; CWI = cold water immersion; MVC = maximum voluntary control

Table A.4

CWI vs CONT for endurance

Included study: Brophy-Williams et al., 2011

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Yo-yo intermittent recovery test	24 hr post (2).	Improved after CWI (completed immediately after fatiguing exercise). No difference after CWI (completed 3 hr after fatiguing exercise).

Note. CWI = cold water immersion; CONT = control

Table A.5

CWI vs CONT for time to failure/exhaustion

Included studies: Crampton et al., 2013; Dunne et al., 2013; McCarthy et al., 2016

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Run to exhaustion	25 min post (2).	Improved after 15 min at 8 ºC but not after 15 min at 15 ºC.
Cycling to exhaustion	15 min (2), 40 min post.	Improved at 15 min (2) and 40 min post.

Note. CWI = cold water immersion; CONT = control

Table A.6

CWI vs CWT for time to failure/exhaustion

Included study: Crampton et al., 2013

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CWT at time point (number of studies 1, unless stated).
Cycling to exhaustion	40 min post.	Increased.

Note. CWI = cold water immersion; CWT = contrast water therapy

Table A.7

ACT vs CWI for time to failure/exhaustion

Included study: Crampton et al., 2013

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CWI at time point (number of studies 1, unless stated).
Cycling to exhaustion	40 min post.	Decreased.

Note. ACT = active; CWI = cold water immersion

Table A.8

CWI vs CONT for soreness

Included studies: Argus et al., 2016; Acensao et al., 2011; Bailey et al., 2007; Brophy-Williams et al., 2011; Corbett et al., 2012; Delextrat et al., Elias et al., 2013; Elias et al., 2012; Fonseca et al., 2016; Getto et al., 2013; Jakeman et al., 2009; King & Duffield, 2009; Pointon & Duffield, 2012; Pournot et al., 2011; Rowsell et al., 2014; White et al., 2014; Yeung et al., 2016

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Perceived soreness (as a whole, and in particular muscle areas)	During recovery, immediately (6), 5 min, 15 min, 20 min, 25 min, within 30 min, 1 hr (9), 2 hr (6), 4 hr, 9 hr, 24 hr (14), 25 hr, 48 hr (11), 72 hr (2), 96 hr and 168 hr (2) post.	No difference during recovery, immediately (4), 5 min, 15 min, 20 min, 25 min, 1 hr (6), 2 hr (5), 4 hr, 24 hr (8), 25 hr, 48 hr (8), 72 hr (2), 96 hr and 168 hr (2) post. Improved immediately post recovery (2) and at within 30 min, 1 hr (3), 2 hr, 9 hr, 24 hr (6) and 48 hr (3) post.

Note. CWI = cold water immersion; CONT = control

Table A.9

CWI vs CWT for soreness

Included studies: Argus et al., 2016; Elias et al., 2013; Elias et al., 2012; King & Duffield, 2009; Pournot et al., 2011

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CWT at time point (number of studies 1, unless stated).
Perceived soreness	Immediately, 5 min, 1 hr (2), 2 hr, 4 hr, 24 hr (4), 25 hr and 48 hr (2) post.	No difference at immediately, 5 min, 1 hr, 2 hr, 4 hr, 24 hr (2) and 25 hr post. Improved at 1 hr, 24 hr (2) and 48 hr (2) post.

Note. CWI = cold water immersion; CWT = contrast water therapy

Table A.10

ACT vs CWI for soreness

Included studies: Corbett et al., 2012; King & Duffield, 2009

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CWI at time point (number of studies 1, unless stated).
Perceived soreness	Immediately, 1 hr, 24 hr (2), 25 hr, 48 hr, 72 hr and 168 hr post.	No difference at 24 hr (2), 25 hr, 48 hr, 72 hr and 168 hr post. Decreased immediately.

Note. ACT = active; CWI = cold water immersion

Table A.11

CWI vs CONT for RPE

Included studies: Crowe et al., 2007; King & Duffield, 2009; McCarthy et al., 2016; Parouty et al., 2010; Rowsell et al., 2014; Stacey et al., 2010; Stanley et al., 2014

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CONT at time point (number of studies 1, unless stated).
RPE	Immediately, 15 min (2), 20 min, 30 min, 40 min, 50 min, 1 hr, 9 hr (8), 24 hr and 25 hr post.	No difference at immediately, 20 min, 30 min, 40 min, 50 min, 1 hr, 9 hr (8), 24 hr and 25 hr post. Improved 15 min (2) post after both CWI at all time points during fatiguing exercise 2 (15 min post; except after the 5 min CWI protocol at the conclusion of the exercise).

Note. CWI = cold water immersion; CONT = control

Table A.12

CWI vs CWT for RPE

Included study: King & Duffield, 2009

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/ worse than CWT at time point (number of studies 1, unless stated).
RPE	Immediately, 24 hr and 25 hr post.	No differences.

Note. CWI = cold water immersion; CWT = contrast water therapy; RPE = rating of perceived exertion

Table A.13

ACT VS CWI for RPE

Included studies: King & Duffield, 2009; Stacey et al., 2010

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CWI at time point (number of studies 1, unless stated).
RPE	Immediately, 20 min, 40 min, 24 hr and 25 hr post.	No differences at 20 min, 40 min, 24 hr and 25 hr post. Increased immediately.

Note. ACT = active; CWI = cold water immersion; RPE = rating of perceived exertion

Table A.14

CWI vs CONT for other perceptual measures

Included studies: Argus et al., 2016; Broatch et al., 2014; Brophy-Williams et al., 2011; Cook & Beaven, 2013; Delextrat et al., Elias et al., 2013; Elias et al., 2012; Fonseca et al., 2016; Garcia et al., 2016; Parouty et al., 2010; Rowsell et al., 2014; Sellwood et al., 2007; Stacey et al., 2010; Stanley et al., 2012; Takeda et al., 2014; White et al., 2014

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Perceived fatigue	Immediately (2), 5 min, 1 hr (2), 2 hr, 4 hr, 24 hr (4) and 48 hr (2) post.	No difference at 5 min, 2 hr, 4 hr, 24 hr (2) post. Improved immediately (2) and at 1 hr (2), 24 hr (2) and 48 hr (2) post.
Pain measures (threshold and tolerance measures of the quadriceps, sit to stand, passive stretch, hopping, running, isometric contraction, tenderness mid-belly, tenderness musculotendinous pain, quadriceps)	Immediately post, 20 min, 40 min, 1 hr, 24 hr (8), 48 hr (8) and 72 hr (7) post.	No difference immediately post, 20 min, 40 min, 1 hr, 24 hr (5), 48 hr (6), 72 hr (7) post. Increased 24 hr (3), 48 hr (2) post.
Perceptual questionnaire (physical and mental readiness for exercise, fatigue, leg soreness, mental and physical recovery, vigour, sleepiness, and muscular pain).	Immediately post (6), 1 hr (6), 1hr 30 min (4), 24 hr (6) and 48 hr (6) post.	No differences immediately post recovery (2), 1 hr (3), 1 hr 30 min (2), 24 hr (5) and 48 (6) hr post. Improved immediately (4) 1 hr (3), 1 hr 30 min (2) and 24 hr post.
Rating of recovery intervention	Conclusion of testing (3).	No differences (2). CWI was believed to be more effective and preferable.
TQR	20 min post, 12 hr (2) and 24 hr (2) post.	No difference at 20 min post. Increased at 12 hr (2) and 24 hr (2) post.
Subjective perceived recovery (general or different areas of the body)	Immediately, 30 min, 1 hr 40 min (3), 9 hr (3), 24 hr and 48 hr post.	No differences immediately, 1 hr 40 min (3), 9 hr (3), 24 hr and 48 hr post. Improved at 30 min post.
Perceived impairment	1 hr (4), 2 hr (4), 24 hr (4) and 48 hr (4) post.	No differences in all studies at all time points.

Note. CWI = cold water immersion; CONT = control; TQR = total quality recovery

Table A.15

CWI vs CWT for other perceptual measures

Included studies: Argus et al., 2016; Elias et al., 2013; Elias et al., 2012; Stanley et al., 2012

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWI improved/not different/worse than CWT at time point (number of studies 1, unless stated).
Perceived fatigue	5 min, 1 hr (2), 2 hr, 4 hr, 24 hr (2) and 48 hr (2) post.	No difference at 5 min, 1 hr (2), 2 hr, 4 hr, 24 hr and 48 hr post. Improved at 24 hr and 48 hr post.
Perceptual questionnaire (fatigue, leg soreness, mental and physical recovery)	1 hr 30 min (4) post.	No difference.

Note. CWI = cold water immersion; CWT = contrast water therapy

Table A.16

ACT vs CWI for other perceptual measures

Included study: Stacey et al., 2010

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CWI at time point (number of studies 1, unless stated).
Pain measures (quadriceps)	20 min and 40 min post.	No difference.
Subjective perceived recovery (legs)	1 hr 40 min (3) post.	No difference.

Note. ACT = active; CWI = cold water immersion

Table A.17

CWT vs CONT for anaerobic performance

Included studies: Argus et al., 2016; Crampton et al., 2011; Elias et al., 2013; Elias et al., 2012; French et al., 2008; Juliff et al., 2014; King & Duffield, 2009; Pournot et al., 2011; Stanely et al., 2012; Vaile et al., 2007

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWT improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Muscle strength variables (MVC)	5 min, 1 hr, 2 hr, 4 hr, 24 hr and 48 hr post.	No difference in all studies at all time points.
Jump variables (power, peak power, velocity, height, flight time: contraction time and flight time)	Immediately, 5 min (2), 1 hr, 2 hr (2), 4 hr (2), 24 hr (9), 25 hr and 48 hr (9) and 72 hr post.	No difference at immediately, 5 min (2), 1hr, 2 hr (2), 4 hr (2), 24 hr (6), 48 hr (7) and 72 hr post. Improved at 24 hr post (3), 25 hr and 48 hr (2) post.
Cycling variables (time trial, average power, peak power, total work)	35 min post (2), 3 hr 25 min post.	No difference at 35 min and 3 hr 25 min post. Improved at 35 min post.
Sprint variables (time, mean and total time)	24 hr (4), 25 hr and 48 hr (3) post.	No difference at 24 hr (2), 48 hr (3). Improved at 24 hr (2) and 25 hr post.
Agility	35 min, 7 hr, 24 hr and 48 hr post.	No difference in all studies at all time points.
Power	1 hr and 24 hr post	No difference in all studies at all time points.
Isometric squat force	Immediately, 24, 48 and 72 hr post.	No difference immediately and at 72 hr post. Less change at 24 and 48 hr post.

Note. CWT = contrast water therapy; CONT = control; MVC = maximum voluntary control

Table A.18

ACT vs CWT for anaerobic performance

Included study: King & Duffield, 2009

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CWT at time point (number of studies 1, unless stated).
Sprint variables (mean and total time)	24 hr (2) and 25 hr post.	No difference in all studies at all time points.
Jump variables	24 hr and 25 hr post.	No difference in all studies at all time points.

Note. ACT = active; CWT = contrast water therapy

Table A.19

CWT vs CONT for time to failure/exhaustion

Included studies: Coffey et al., 2004; Crampton et al., 2011; Crampton et al., 2013

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWT improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Runs to exhaustion	4 hr post.	No difference in all studies at all time points.
Cycling to exhaustion (time to failure and total work)	35 min (2) and 40 min post.	Improved at 35 min (2) and 40 min.

Note. CWT = contrast water therapy; CONT = control

Table A.20

ACT vs CWT for time to failure/exhaustion

Included studies: Coffey et al., 2004; Crampton et al., 2013

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CWT at time point (number of studies 1, unless stated).
Runs to exhaustion	4 hr post.	No difference in all studies at all time points.
Cycling to exhaustion	40 min post.	Decreased.

Note. ACT = active; CWT = contrast water therapy

Table A.21

CWT vs CONT for soreness

Included studies: Argus et al., 2016; Elias et al., 2013; Elias et al., 2012; French et al., 2008; King & Duffield, 2009; Pournot et al., 2011; Vaile et al., 2007

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWT improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Perceived soreness	Immediately (2), 5 min, 1 hr (3), 2 hr, 4 hr, 24 hr (7), 25 hr and 48 hr (4) and 72 hr post.	No difference at immediately, 5 min, 1 hr (2), 2 hr, 4 hr, 24 hr (4), 25 hr and 48 hr (2) post. Improved at immediately, 1 hr, 24 hr (3) and 48 hr (2).

Note. CWT = contrast water therapy; CONT = control

Table A.22

ACT vs CWT for soreness

Included study: King & Duffield, 2009

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CWT at time point (number of studies 1, unless stated).
Perceived soreness	Immediately, 24 hr and 25 hr post.	No difference at 24 hr and 25 hr post. Decreased immediately.

Note. ACT = active; CWT = contrast water therapy

Table A.23

CWT vs CONT for RPE

Included study: King & Duffield, 2009

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWT improved/not different/ worse than CONT at time point (number of studies 1, unless stated).
RPE	Immediately, 24 hr and 25 hr post.	No differences.

Note. CWT = contrast water therapy; CONT = control; RPE = rating of perceived exertion

Table A.24

ACT vs CWT for RPE

Included study: King & Duffield, 2009

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/ worse than CWT at time point (number of studies 1, unless stated).
RPE	Immediately, 24 hr and 25 hr post.	No differences at 20 min, 40 min, 24 hr and 25 hr post. Increased immediately.

Note. ACT = active; CWT = contrast water therapy; RPE = rating of perceived exertion

Table A.25

CWT vs CONT for other perceptual measures

Included studies: Argus et al., 2016; Coffey et al., 2004; Elias et al., 2013; Elias et al., 2012; French et al., 2008; Juliff et al., 2014; Stanley et al., 2012

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	CWT improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Perceived fatigue	5 min, 35 min, 1 hr (2), 2 hr, 4 hr, 5 hr, 24 hr (3) and 48 hr (2) post.	No difference at 5 min, 35 min, 1 hr, 2 hr, 4 hr, 5 hr, 24 hr and 48 hr post. Improved at 1 hr, 24 hr (2) and 48 hr post.
RPErec	Immediately and shortly after recovery, before and immediately after fatiguing exercise bout 2 (4 hr post).	No differences.
Perceived pain	1 hr, 24 hr and 48 hr post.	No differences.
Rating of recovery intervention	Conclusion of testing.	Improved.
Perceptual questionnaire (fatigue, leg soreness, mental and physical recovery)	1 hr 30 min (4) post0	No difference (2). Improved (2).

Note. CWT = contrast water therapy; CONT = control; RPErec = rating of perceived exertion recovery

Table A.26

ACT vs CWT for other perceptual measures

Included study: Coffey et al., 2004

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CWT at time point (number of studies 1, unless stated).
RPErec	Immediately and shortly after recovery, before and immediately after fatiguing exercise bout 2.	No differences.

Note. ACT = active; CWT = contrast water therapy; RPErec = rating of perceived exertion recovery

Table A.27

ACT vs CONT for anaerobic performance

Included studies: Corbett et al., 2012; King & Duffield, 2009; Stacey et al., 2010

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Sprint variables (mean and total time)	24 hr (2) and 25 hr post.	No difference in all studies at all time points.
Jump variables	24 hr and 25 hr post.	No difference in all studies at all time points.
Cycling variables (time trial)	20 and 40 min post.	No difference in all studies at all time points.
MVC	24, 48, 72 and 168 hr post.	No difference in all studies at all time points.
Hop test	24 hr, 48 hr, 72 hr and 168 hr post.	No difference in all studies at all time points.

Note. ACT = active; CONT = control; MVC = maximum voluntary contraction

Table A.28

ACT vs CONT for time to failure/exhaustion

Included studies: Coffey et al., 2004; Crampton et al., 2013

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Runs to exhaustion	4 hr post.	No difference in all studies at all time points.
Cycling to exhaustion	40 min post.	No difference in all studies at all time points.

Note. ACT = active; CONT = control

Table A.29

ACT vs CONT for soreness

Included studies: Corbett et al., 2012; King & Duffield, 2009

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CONT at time point (number of studies 1, unless stated).
Perceived soreness	Immediately, 1 hr, 24 hr (2), 25 hr, 48 hr, 72 hr and 168 hr post.	No difference in all studies at all time points.

Note. ACT = active; CONT = control

Table A.30

ACT vs CONT for RPE

Included studies: King & Duffield, 2009; Stacey et al., 2010

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CONT at time point (number of studies 1, unless stated).
RPE	Immediately, 20 min, 40 min, 24 hr and 25 hr post.	No differences at 20 min, 40 min, 24 hr and 25 hr post. Increased immediately.

Note. ACT = active; CONT = control; RPE = rating of perceived exertion

Table A.31

ACT vs CONT for other perceptual measures

Included studies: Coffey et al., 2004; Stacey et al., 2010

Variable	Time post fatiguing exercise/recovery (number of studies 1, unless stated)	ACT improved/not different/worse than CONT at time point (number of studies 1, unless stated).
RPErec	Immediately and shortly after recovery, before and immediately after fatiguing exercise bout 2 (4 hr post).	No differences.
Pain measures (quadriceps)	20 min and 40 min post.	No difference.
Subjective perceived recovery (legs)	1 hr 40 min (3) post.	No difference.

Note. ACT = active; CONT = control; RPErec = rating of perceived exertion recovery

Appendix B: Ethics Approval - Team Sport Athletes' Understanding of Recovery Strategies

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Appendix C: Chapter 3 Survey

Use of Post-Exercise Recovery Strategies in Team Sports

JAMES COOK UNIVERSITY
AUSTRALIA

Townsville Campus

Townsville Qld 4811 Australia
Telephone (07) 4781 4111
International +61 7 4781 4111

SECTION A: DEMOGRAPHIC INFORMATION

1. Name the major sport that you play: ___________________
2. Highest level of competition that you are currently competing in for the selected sport (please circle):

   Local Regional State National International

3. Your current age: _________
4. Your gender (please circle): male female
5. Over which months do you compete in the sport (e.g. March-September)?

   ____

6. On average, how many competition games/matches/events do you perform each week? ___________________
7. On average, how much time each week would you spend competing in the sport (i.e. competition game, match or event)? ________________
8. On average, how much time each week would you spend training for this sport (include all training: skills, conditioning)? ________________

SECTION B: GENERAL RECOVERY INFORMATION

1. Do you undertake recovery after competition (please circle)? YES or NO
2. Do you undertake recovery after pre-season training (please circle)? YES or NO
3. Do you undertake recovery after in-season training (please circle)? YES or NO

If you answered no to all of questions 1, 2 and 3, skip to question 6 (over-page).

If you answered yes to any of questions 1, 2 or 3, proceed to question 4 (below).

4. Select all of the recovery activities that you undertake after competition, after pre-season training and after in-season training:

Recovery activity	**Performed after competition (tick if yes)**	**Performed after pre-season training (tick if yes)**	**Performed after in-season training (tick if yes)**
Active land-based recovery: e.g. walk, cycle, slow jog			
Active pool-based recovery			
Active stretching cool down			
Cold/ice bath/shower			
Contrast bath/shower			
Massage			
Sleep/nap			
Food and/or fluid replacement			
Ice pack/vest application			
Heat pack application			
Liniment or gel application			
Progressive muscle relaxation or imagery			
Prayer or music			
Reflexology or acupuncture			
Supplement use			
Medication use			
Other (please specify)			

5. Of all the recovery strategies you have undertaken, which have you found to be the most effective?

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After completing question 5, proceed to Section C

6. If you do not perform recovery activities after competition or training, can you please tell us in your own words why you do not.

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If you do not perform recovery activities after competition or training, and have completed question 6, you have now finished the survey. Thank you for your time.

SECTION C: ACTIVE, LAND-BASED RECOVERY

Definition: active, land-based recovery includes activities such as or similar to walking, slow jogging, low intensity cycling. Do not include stretching or water-based activities in this section.

1. How often do you perform active land-based recovery after competition (please circle)?

   always sometimes rarely never

2. How often do you perform active land-based recovery after pre-season training (please circle)?

   always sometimes rarely never

3. How often do you perform active land-based recovery after in-season training (please circle)?

   always sometimes rarely never

If you answered 'never' to all of these questions, skip to section D.
If you answered 'always', 'sometimes' or 'rarely' to any of these questions, proceed with this section.

4. How effective on a scale of 1-5 do you believe active land-based recovery is (please circle)?

   1 = not at all effective 3 = neither effective nor ineffective 5 = very effective

   1 2 3 4 5

5. Please explain why you believe active land-based recovery is an effective or ineffective recovery strategy, as identified in question 4.

Please proceed to question 6 and 7

6. Reasons why an active, land-based recovery would be performed are listed below. Please read the list and then rate how important you believe each of these reasons are for you. **Rate from 1 to 5 for each item. 1 = not important reason**
3 = neither important nor unimportant reason 5 = very important reason

I perform an active, land-based recovery, because it…	**Rating 1-5 (please circle)**
Helps me to wind down and relax	1 2 3 4 5
Gives me time to socialise with team mates	1 2 3 4 5
Gives me time to reflect on the training session or match	1 2 3 4 5
Makes me feel good	1 2 3 4 5
Is what I have seen the elite athletes do	1 2 3 4 5
Is something the coach told me to do	1 2 3 4 5
Will increase muscle performance	1 2 3 4 5
Speeds up removal of waste product from muscles	1 2 3 4 5
Decreases muscle soreness	1 2 3 4 5
Reduces swelling and inflammation	1 2 3 4 5
Reduces muscle spasms	1 2 3 4 5
Increases blood circulation	1 2 3 4 5
Reduces stress and anxiety	1 2 3 4 5
Makes me feel energetic	1 2 3 4 5
Can improve healing	1 2 3 4 5
Helps me to switch off	1 2 3 4 5
Helps me to be able to train/compete hard again in the next session/game	1 2 3 4 5
Lowers heart rate	1 2 3 4 5
Creates a pumping action in the muscles	1 2 3 4 5
Other (please specify)	1 2 3 4 5

7. Please provide details of what your active land-based recovery session consists of. If you perform different types of recovery strategies, please provide the details for each session:

GAME/TRAINING SESSION TYPE **(game, skills training, aerobic conditioning, resistance training, etc). If the same recovery is used for multiple sessions, clump sessions together**	**RECOVERY DETAILS** **Description of what you do in this recovery (e.g. team walk; stationary cycling)**	**DURATION OF RECOVERY** **(in minutes)**	**INTENSITY OF RECOVERY** **(low, moderate, high)**	**HOW LONG AFTER THE SESSION IS THE RECOVERY PERFORMED?** **(e.g. within 1 hr, within 12 hours, within 24 hours)**

SECTION D: ACTIVE, WATER-BASED RECOVERY

Definition: active, water-based recovery includes activities such as or similar to swimming, pool walking, pool jogging. Do not include non-active cold water/ice or heated/contrast water-based immersion in this section.

1. How often do you perform active water-based recovery after competition (please circle)?

   always sometimes rarely never

2. How often do you perform active water-based recovery after pre-season training (please circle)?

   always sometimes rarely never

3. How often do you perform active water-based recovery after in-season training (please circle)?

   always sometimes rarely never

If you answered 'never' to all of these questions, skip to section E.
If you answered 'always', 'sometimes' or 'rarely' to any of these questions, proceed with this section.

4. How effective on a scale of 1-5 do you believe active water-based recovery is (please circle)?

   1 = not at all effective 3 = neither effective nor ineffective 5 = very effective

   1 2 3 4 5

   ←————————————————→

5. Please explain why you believe active water-based recovery is an effective or ineffective recovery strategy, as identified in question 4.

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Proceed to question 6 and 7

6. Reasons why an active, water-based recovery would be performed are listed below. Please read the list and then rate how important you believe each of these reasons are for you. **Rate from 1 to 5 for each item. 1 = not important reason**
3 = neither important nor unimportant reason **5 = very important reason**

I perform an active, water-based recovery, because it…	**Rating 1-5 (please circle)**
Will increase muscle performance	1 2 3 4 5
Is what I have seen the elite athletes do	1 2 3 4 5
Is something the coach told me to do	1 2 3 4 5
Helps me to wind down and relax	1 2 3 4 5
Gives me time to socialise with team mates	1 2 3 4 5
Gives me time to reflect on the training session or match	1 2 3 4 5
Makes me feel good	1 2 3 4 5
Reduces muscle spasms	1 2 3 4 5
Increases blood circulation	1 2 3 4 5
Reduces stress and anxiety	1 2 3 4 5
Makes me feel energetic	1 2 3 4 5
Reduces swelling and inflammation	1 2 3 4 5
Can improve healing	1 2 3 4 5
Helps me to switch off	1 2 3 4 5
Helps me to be able to train/compete hard again in the next session/game	1 2 3 4 5
Lowers heart rate	1 2 3 4 5
Creates a pumping action in the muscles	1 2 3 4 5
Speeds up removal of waste products from muscles	1 2 3 4 5
Decreases muscle soreness	1 2 3 4 5
Other (please specify)	1 2 3 4 5

7. Please provide details of what your active water-based recovery session consists of. If you perform different types of recovery strategies, please provide the details for each session:

GAME/TRAINING SESSION TYPE (game, skills training, aerobic conditioning, resistance training, etc). If the same recovery is used for multiple sessions, clump sessions together	**RECOVERY DETAILS** Description of what you do in this recovery (e.g. swimming, pool walking) INCLUDE IF WATER IS HEATED OR UN-HEATED.	**DURATION OF RECOVERY** (in minutes)	**INTENSITY OF RECOVERY** (low, moderate, high)	**HOW LONG AFTER THE SESSION IS THE RECOVERY PERFORMED?** (e.g. within 1 hr, within 12 hours, within 24 hours)

SECTION E: STRETCHING RECOVERY

Definition: stretching recovery includes static stretching, PNF stretching, or dynamic stretching.

Static stretching = hold stretch in a stationary position for usually 15-30 seconds

PNF stretching = partner assists with the stretching

Dynamic stretching = dynamic movement such as leg swings, arm swings, high knees, butt kicks, skipping.

1. How often do you perform stretching recovery after competition (please circle)?

   always   sometimes   rarely   never

2. How often do you perform stretching recovery after pre-season training (please circle)?

   always   sometimes   rarely   never

3. How often do you perform stretching recovery after in-season training (please circle)?

   always   sometimes   rarely   never

If you answered 'never' to all of these questions, skip to section F.

If you answered 'always', 'sometimes' or 'rarely' to any of these questions, proceed with this section.

4. How effective on a scale of 1-5 do you believe stretching recovery is (please circle)?

   1 = not at all effective   3 = neither effective nor ineffective   5 = very effective

   1   2   3   4   5

5. Please explain why you believe stretching recovery is an effective or ineffective recovery strategy, as identified in question 4.

Proceed to question 6 and 7

6. Reasons why stretching recovery would be performed are listed below. Please read the list and then rate how important you believe each of these reasons are for you.

Rate from 1 to 5 for each item. 1 = not important reason

3 = neither important nor unimportant reason **5 = very important reason**

I perform stretching recovery, because it…	**Rating 1-5 (please circle)**
Reduces swelling and inflammation	1 2 3 4 5
Gives me time to socialise with team mates	1 2 3 4 5
Gives me time to reflect on the training session or match	1 2 3 4 5
Helps me to wind down and relax	1 2 3 4 5
Reduces muscle spasms	1 2 3 4 5
Will increase muscle performance	1 2 3 4 5
Speeds up removal of waste product from muscles	1 2 3 4 5
Decreases muscle soreness	1 2 3 4 5
Can improve healing	1 2 3 4 5
Makes me feel good	1 2 3 4 5
Is what I have seen the elite athletes do	1 2 3 4 5
Helps me to be able to train/compete hard again in the next session/game	1 2 3 4 5
Lowers heart rate	1 2 3 4 5
Increases blood circulation	1 2 3 4 5
Reduces stress and anxiety	1 2 3 4 5
Makes me feel energetic	1 2 3 4 5
Is something the coach told me to do	1 2 3 4 5
Helps me to switch off	1 2 3 4 5
Creates a pumping action in the muscles	1 2 3 4 5
Other (please specify)	1 2 3 4 5

7. Please provide details of what your stretching recovery session consists of. If you perform different types of recovery strategies, please provide the details for each session:

GAME/TRAINING SESSION TYPE (game, skills training, aerobic conditioning, resistance training, etc). If the same recovery is used for multiple sessions, clump sessions together	**RECOVERY DETAILS** Description of what you do in this recovery (e.g. type of stretching – static, PNF, dynamic)	**DURATION OF RECOVERY** (in minutes)	**INTENSITY OF RECOVERY** (low, moderate, high)	**HOW LONG AFTER THE SESSION IS THE RECOVERY PERFORMED?** (e.g. within 1 hr, within 12 hours, within 24 hours)

SECTION F: COLD WATER RECOVERY

Definition: cold water recovery includes immersion in cold water or ice water

1. How often do you perform cold water recovery after competition (please circle)?

   always sometimes rarely never

2. How often do you perform cold water recovery after pre-season training (please circle)?

   always sometimes rarely never

3. How often do you perform cold water recovery after in-season training (please circle)?

   always sometimes rarely never

If you answered 'never' to all of these questions, skip to section G.

If you answered 'always', 'sometimes' or 'rarely' to any of these questions, proceed with this section.

4. How effective on a scale of 1-5 do you believe cold water recovery is (please circle)?

   1 = not at all effective 3 = neither effective nor ineffective 5 = very effective

   1 2 3 4 5

5. Please explain why you believe cold water recovery is an effective or ineffective recovery strategy, as identified in question 4.

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Proceed to question 6 and 7

6. Reasons why cold water recovery would be performed are listed below. Please read the list and then rate how important you believe each of these reasons are for you.

   Rate from 1 to 5 for each item. 1 = not important reason

   3 = neither important nor unimportant reason 5 = very important reason

I perform cold water recovery, because it…	**Rating 1-5 (please circle)**
Helps me to wind down and relax	1 2 3 4 5
Can improve healing	1 2 3 4 5
Gives me time to reflect on the training session or match	1 2 3 4 5
Makes me feel good	1 2 3 4 5
Is what I have seen the elite athletes do	1 2 3 4 5
Is something the coach told me to do	1 2 3 4 5
Helps me to switch off	1 2 3 4 5
Helps me to be able to train/compete hard again in the next session/game	1 2 3 4 5
Lowers heart rate	1 2 3 4 5
Creates a pumping action in the muscles	1 2 3 4 5
Gives me time to socialise with team mates	1 2 3 4 5
Reduces muscle spasms	1 2 3 4 5
Increases blood circulation	1 2 3 4 5
Reduces stress and anxiety	1 2 3 4 5
Makes me feel energetic	1 2 3 4 5
Will increase muscle performance	1 2 3 4 5
Speeds up removal of waste product from muscles	1 2 3 4 5
Decreases muscle soreness	1 2 3 4 5
Reduces swelling and inflammation	1 2 3 4 5
Other (please specify)	1 2 3 4 5

7. Please provide details of what your cold water recovery session consists of. If you perform different types of recovery strategies, please provide the details for each session:

GAME/TRAINING SESSION TYPE **(game, skills training, aerobic conditioning, resistance training, etc).** **If the same recovery is used for multiple sessions, clump sessions together**	**TYPE OF COLD WATER RECOVERY** **Apparatus used: bath, pool, shower, bin etc** **Water level: to hips, to waist, to chest, to shoulder, to neck, whole body**	**DURATION OF RECOVERY** **(in minutes) duration of each immersion and number of imemrsions**	**WATER SOURCE & TEMPERATURE** **Source: tap, ice, fridge, etc** **Temperature: in degrees OR** **Cool, cold, very cold, unbearably cold, freezing**	**HOW LONG AFTER THE SESSION IS THE RECOVERY PERFORMED?** **(e.g. within 1 hr, within 12 hours, within 24 hours)**
	Apparatus: Water level:	Duration of each immersion: number of cycles:	Source: Temperature:	
	Apparatus: Water level:	Duration of each immersion: number of cycles:	Source: Temperature:	
	Apparatus: Water level:	Duration of each immersion: number of cycles:	Source: Temperature:	
	Apparatus: Water level:	Duration of each immersion: number of cycles:	Source: Temperature:	
	Apparatus: Water level:	Duration of each immersion: number of cycles:	Source: Temperature:	

SECTION G: CONTRAST WATER RECOVERY

Definition: contrast water recovery includes alternation between cold water immersion and hot water immersion.

1. How often do you perform contrast water recovery after competition (please circle)?

   always sometimes rarely never

2. How often do you perform contrast water recovery after pre-season training (please circle)?

   always sometimes rarely never

3. How often do you perform contrast water recovery after in-season training (please circle)?

   always sometimes rarely never

If you answered 'never' to all of these questions, you have now finished the survey, thank you for your time.

If you answered 'always', 'sometimes' or 'rarely' to any of these questions, proceed with this section.

4. How effective on a scale of 1-5 do you believe contrast water recovery is (please circle)?

   1 = not at all effective 3 = neither effective nor ineffective 5 = very effective

   1 2 3 4 5

5. Please explain why you believe contrast water recovery is an effective or ineffective recovery strategy, as identified in question 4.

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Proceed to question 6 and 7

6. Reasons why contrast water recovery would be performed are listed below. Please read the list and then rate how important you believe each of these reasons are for you.

   Rate from 1 to 5 for each item. 1 = not important reason

   3 = neither important nor unimportant reason   5 = very important reason

I perform contrast water recovery, because it…	**Rating 1-5 (please circle)**
Will increase muscle performance	1 2 3 4 5
Helps me to wind down and relax	1 2 3 4 5
Speeds up removal of waste product from muscles	1 2 3 4 5
Decreases muscle soreness	1 2 3 4 5
Reduces swelling and inflammation	1 2 3 4 5
Gives me time to socialise with team mates	1 2 3 4 5
Gives me time to reflect on the training session or match	1 2 3 4 5
Makes me feel good	1 2 3 4 5
Is what I have seen the elite athletes do	1 2 3 4 5
Is something the coach told me to do	1 2 3 4 5
Reduces muscle spasms	1 2 3 4 5
Helps me to switch off	1 2 3 4 5
Helps me to be able to train/compete hard again in the next session/game	1 2 3 4 5
Lowers heart rate	1 2 3 4 5
Increases blood circulation	1 2 3 4 5
Makes me feel energetic	1 2 3 4 5
Can improve healing	1 2 3 4 5
Creates a pumping action in the muscles	1 2 3 4 5
Reduces stress and anxiety	1 2 3 4 5
Other (please specify)	1 2 3 4 5

7. Provide details of your contrast water recovery sessions. If you perform different types of recovery strategies, provide the details for each session:

GAME/TRAINING SESSION TYPE **(game, skills training, aerobic conditioning, resistance training, etc).** **If the same recovery is used for multiple sessions, clump sessions together**	**TYPE OF CONTRAST WATER RECOVERY** **Apparatus used: bath, pool, shower, bin etc** **Water level: to hips, to waist, to chest, to shoulder, to neck, whole body**	**DURATION OF RECOVERY** **(in minutes)** **Duration in cold water** **Duration in hot water**	**WATER SOURCE AND TEMPERATURE** **Source: tap, ice, fridge, etc** **Temperature: in degrees OR COLD: Cool, cold, very cold, unbearably cold, freezing** **HOT: warm, hot, very hot, unbearably hot, boiling**	**HOW LONG AFTER THE SESSION IS THE RECOVERY PERFORMED?** **(e.g. within 1 hr, within 12 hours, within 24 hours)**
	Cold apparatus: Cold water level: Hot apparatus: Hot water level:	Cold duration each cycle: Hot duration each cycle: Number of repeat cycles:	Cold water source: Cold water temperature: Hot water source: Hot water temperature:	
	Cold apparatus: Cold water level: Hot apparatus: Hot water level:	Cold duration each cycle: Hot duration each cycle: Number of repeat cycles:	Cold water source: Cold water temperature: Hot water source: Hot water temperature:	
	Cold apparatus: Cold water level: Hot apparatus: Hot water level:	Cold duration each cycle: Hot duration each cycle: Number of repeat cycles:	Cold water source: Cold water temperature: Hot water source: Hot water temperature:	
	Cold apparatus: Cold water level: Hot apparatus: Hot water level:	Cold duration each cycle: Hot duration each cycle: Number of repeat cycles:	Cold water source: Cold water temperature: Hot water source: Hot water temperature:	
	Cold apparatus: Cold water level: Hot apparatus: Hot water level:	Cold duration each cycle: Hot duration each cycle: Number of repeat cycles:	Cold water source: Cold eater temperature: Hot water source: Hot water temperature:	

8. Select which water therapy you start your contrast water recovery session with (please circle): cold water   Hot water

You have now completed this survey, thank you for your time

Appendix D: Ethics Approval - Influence of Recovery Strategies on Performance and Perceptions Following a Single Simulated Team-game Fatiguing Exercise

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Appendix E: Chapter 4 and 5 DALDA Questionnaire

DALDA Questionnaire

Monitors state of well being and mood state

(a = worse than normal, b = normal, c = better than normal)

Part A

1. a b c Diet
2. a b c Home Life
3. a b c School / college / work
4. a b c Friends
5. a b c Sports Training
6. a b c Climate
7. a b c Sleep
8. a b c Recreation
9. a b c Health

Part B

1. a b c Muscle Pains
2. a b c Techniques
3. a b c Tiredness
4. a b c Need for rest
5. a b c Supplementary Work
6. a b c Boredom
7. a b c Recovery Time
8. a b c Irritability
9. a b c Weight
10. a b c Throat
11. a b c Internal
12. a b c Unexplained aches
13. a b c Technique Strength
14. a b c Enough Sleep
15. a b c Between Session Recovery
16. a b c General Weakness
17. a b c Interest
18. a b c Arguments
19. a b c Skin Rashes
20. a b c Congestion
21. a b c Training Effort
22. a b c Temper
23. a b c Swelling
24. a b c Likability
25. a b c Runny Nose

(Rushall, 1990)

Appendix F: Chapter 4 and 5 Ratings of Perceived Exertion and Total Quality Recovery Scale

Ratings of Perceived Exertion

Total Quality Recovery Scale

Ratings of perceived exertion (RPE)	Total quality recovery (TQR)
6	6
7 Very, very light	7 Very, very poor recovery
8	8
9 Very light	9 Very poor recovery
10	10
11 Fairly light	11 Poor recovery
12	12
13 Somewhat hard	13 Reasonable recovery
14	14
15 Hard	15 Good recovery
16	16
17 Very hard	17 Very good recovery
18	18
19 Very, very hard	19 Very, very good recovery
20	20

(Kenttä & Hassmén, 1998)

Appendix G: Chapter 4 and 5 Soreness Scale

Soreness Scale

	0 = No pain
	1
	2
	3
How do your Muscles feel?	4
	5
	6
	7
	8
	9
	10 = very very sore

(Pointon & Duffield, 2012)

Appendix H: Ethics Approval - Effects of Various Recovery Strategies on Repeated Simulated Small-sided Team Sport Demands

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Appendix I: Chapter 5 Karolinska Sleepiness Scale

Karolinska Sleepiness Scale

Extremely Alert	1
Very alert	2
Alert	3
Rather alert	4
Neither alert nor sleepy	5
Some signs of sleepiness	6
Sleepy, but no effort to keep awake	7
Sleepy, but some effort to keep awake	8
Very sleepy, great effort to keep awake, fighting sleep	9
Extremely sleepy, can't keep awake	10

(Shahid et al., 2012)

Appendix J: Chapter 5 Sleep Quality Scale

Sleep Quality

Very good	1
	2
	3
	4
Very poor	5

(Robey et al., 2014)