Influence of Recovery Modalities on Team Sport Performance, Perceptions and Physiological Variables

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2011

This thesis is submitted as partial fulfilment of the requirements for the degree of Bachelor of Sports Science (Honours) at Murdoch University, Perth, Western Australia.
I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

(Miss Laura Juliff)
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ABSTRACT

Purpose: In order to cope with the demands and stress of training and competition many team sports have begun to utilise contrast water therapy as their preferred recovery modality. Although popular, there may be an inability to access necessary facilities when at sporting venues or overseas therefore contrast showers may prove to be a convenient, accessible and effective alternative. Research examining the influence of contrast showers on sport performance and psychological and physiological variables is lacking. Therefore, this study sought to examine the effects of contrast showers and contrast water therapy on vertical jump and repeated agility performance, skin and core temperature and psychological measures following a netball specific circuit in elite female netball players. Methods: Eleven elite netball players completed three experimental sessions (randomised crossover design) followed by one of three post-exercise recovery interventions; (1) contrast water therapy (CWT, 38°C and 15°C), (2) contrast showers (CS, 38°C and 18°C) and (3) passive recovery (PAS, seated rest 20°C). For each trial, participants performed a fatiguing netball specific circuit followed by one of the recovery interventions. Repeated agility, repeated vertical jump, skin and core temperature and muscle soreness were measured before, immediately after, 5 hours post and 24 hours post-exercise. Results: No significant differences (p > 0.05) were evident between conditions for exercise performance (vertical jump, repeated agility). Post-exercise CWT and CS provided similar cooling effects through decreased skin temperature ($T_{skin}$) results and a delayed drop in core temperature ($T_{core}$) of (-1.0%) when compared to a passive condition. Perceived perceptions overall were greater in the CWT (18.95 ± 13.77) and CS (17.70 ± 12.98) conditions when compared with a passive recovery (72.80 ± 14.26). Furthermore, a significant (P<0.001) change in
perception of CS recovery conditions was observed pre and post condition indicating a significant favourable change in perception. **Conclusion:** Although no improvements in performance were noted after CWT or CS, neither modality negatively influenced performance. Furthermore, both CWT and CS resulted in faster cooling responses and greater perceptions of recovery when compared with passive sitting. For this reason, it is suggested that CWT and CS are viable recovery modalities that can be used to help increase recovery in netballers after intense training or competition scenarios.
DEFINITION OF TERMS

For consistency of interpretation the preceding words are defined:

**Active recovery**: Low intensity exercise conducted post-exercise.

**Agility**: Ability to effectively and efficiently move and change direction of the body.

**Contrast Water Therapy (CWT)**: The alternation of cold and hot water immersion.

**Cold Water Immersion (CWI)**: The Immersion of the body in water temperatures of less than 15°C.

**Hot Water Immersion (HWI)**: The Immersion of the body in water temperatures greater than 37°C.

**Hydrostatic Pressure**: Pressure exerted on the body through the weight of fluid.

**Passive Recovery**: A form of post-exercise recovery that involves periods of rest (i.e. passive sitting).

**Recovery**: A process of restoring the body physiologically and psychologically to pre-exercise levels following exercise.

**Vasoconstriction**: Narrowing of the blood vessels that increase peripheral resistance.

**Vasodilation**: Relaxation of the smooth muscles of the blood vessels that decreases peripheral resistance.
### ABBREVIATIONS

Selected abbreviations used throughout the text

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td><strong>AFL:</strong></td>
<td>Australian Football League</td>
</tr>
<tr>
<td><strong>AIS:</strong></td>
<td>Australian Institute of Sport</td>
</tr>
<tr>
<td><strong>ANOVA:</strong></td>
<td>analysis of variance</td>
</tr>
<tr>
<td><strong>ATP:</strong></td>
<td>adenosinetriphosphate</td>
</tr>
<tr>
<td><strong>bpm:</strong></td>
<td>beats per minute</td>
</tr>
<tr>
<td><strong>C:</strong></td>
<td>centre netball position</td>
</tr>
<tr>
<td><strong>˚C:</strong></td>
<td>temperature in degrees centigrade</td>
</tr>
<tr>
<td><strong>CHO:</strong></td>
<td>carbohydrate</td>
</tr>
<tr>
<td><strong>CMJ:</strong></td>
<td>counter movement jump</td>
</tr>
<tr>
<td><strong>CNS:</strong></td>
<td>central nervous system</td>
</tr>
<tr>
<td><strong>CS:</strong></td>
<td>contrast showers</td>
</tr>
<tr>
<td><strong>CWI:</strong></td>
<td>cold water immersion</td>
</tr>
<tr>
<td><strong>CWT:</strong></td>
<td>contrast water therapy</td>
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<tr>
<td><strong>DOMS:</strong></td>
<td>delayed onset muscle soreness</td>
</tr>
<tr>
<td><strong>GK:</strong></td>
<td>goal keeper netball position</td>
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<tr>
<td><strong>GS:</strong></td>
<td>goal shooter netball position</td>
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<tr>
<td><strong>HWI:</strong></td>
<td>hot water immersion</td>
</tr>
<tr>
<td><strong>ISAK:</strong></td>
<td>International Society for the Advancement of Kinanthropometry</td>
</tr>
<tr>
<td><strong>kg:</strong></td>
<td>kilogram</td>
</tr>
<tr>
<td><strong>PAS:</strong></td>
<td>passive recovery</td>
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<td><strong>PostEx:</strong></td>
<td>post-exercise measurement</td>
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<tr>
<td><strong>PostRec:</strong></td>
<td>post-recovery measurement</td>
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<tr>
<td><strong>RPE:</strong></td>
<td>rate of perceived exertion</td>
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<tr>
<td><strong>Tcore:</strong></td>
<td>core temperature</td>
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<tr>
<td><strong>Tmean:</strong></td>
<td>mean body temperature</td>
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<tr>
<td><strong>Tskin:</strong></td>
<td>skin temperature</td>
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<tr>
<td><strong>VAS:</strong></td>
<td>visual analogue scale</td>
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<tr>
<td><strong>W:R:</strong></td>
<td>work to rest ratio</td>
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CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Recovery is an important component of an athlete’s training regime. As athletes strive to maximise their athletic potential and improve performance they engage in large training loads\textsuperscript{38, 80}. This can lead to an athlete becoming overreached\textsuperscript{41} or overtrained\textsuperscript{41}. A balance between achieving peak performance and avoiding the negative consequences of fatigue (i.e. overtraining and possibly injury) must be attained to allow athletes the greatest likelihood of positive adaptations to either training or competition stressors\textsuperscript{30, 40, 66, 76}. In fact, Vaile, Halson and Graham\textsuperscript{76} suggest that the rate and quality of recovery prescribed to an elite athlete may be as important as the training itself. Coaches, athletes and sports science professionals have therefore begun to focus greater attention on the need to incorporate recovery sessions into training programs.

In an attempt to optimise recovery, athletes can chose from numerous established recovery modalities (e.g. active and passive recovery, compression garments, sleep, nutritional strategies such as post-exercise supplementation, massage, stretching, cold water immersion (CWI), hot water immersion (HWI), contrast water therapy (CWT) and contrast showers (CS))\textsuperscript{30, 43, 81}. Current scientific evidence indicates that immersion in water (hydrotherapy) may be superior to more traditional approaches such as active recovery (i.e. walking, jogging)\textsuperscript{16, 32, 33, 46}. Coffey et al.\textsuperscript{17} observed greater perceptions of recovery after water immersion (alternating 2 minutes hot; 42°C, 1 minute cold; 10°C repeated five times), compared with active recovery following treadmill runs to exhaustion at 120% and 90% of peak running speed. In addition, significantly lower blood lactate concentration and heart rate were observed in 20 rugby players when using
hydrotherapy as a recovery modality after a series of repeat sprint tests (ten 40-m sprints with a 30-sec turn-around between sprints) compared to an active recovery. Thus, one benefit of hydrotherapy compared to active recovery is the ability to increase blood flow and metabolite removal; yet, unlike active recovery there is no need to expend additional energy stores. During hydrotherapy the immersed body part(s) are exposed to hydrostatic pressure, creating a displacement of fluids from the periphery to the central cavity, resulting in multiple physiological changes such as an increase in substrate transport, improved metabolic waste clearance, increased stroke volume and cardiac output as well as a reduction in peripheral resistance. In addition to the pressure associated with water immersion, the temperature of the water itself can influence the effectiveness of the recovery modality. For these reasons, the use of water immersion as a recovery modality is now commonly practiced within elite sport settings. Currently there are four established modes of water immersion; CWI, HWI, CWT and thermal neutral immersion.

Cold water immersion is defined as immersion in water temperatures of less than 15°C and is commonly used for the treatment of inflammation, spasm and pain, and to rapidly reduce core temperature. Beneficial influences of CWI have been observed and include: vasoconstriction, enhanced venous return, decreases in swelling, tissue temperature, skin temperature, heart rate and cardiac output, enhanced creatine kinase clearance and analgesic effects that alter pain perception. Additionally, cryotherapy has been shown to reduce secondary muscle damage by slowing cell metabolism and nerve conduction, and reducing neutrophil migration and cell necrosis and that in some instances may prove to be beneficial. Following exercise in the heat, the use of CWI during recovery can
increase subsequent athletic performance. For instance, Peiffer et al.\textsuperscript{52} observed a significant improvement in subsequent endurance performance in the heat after a 15 minute CWI (14°C) recovery session compared to passive sitting in a thermoneutral environment.

Currently there is limited research examining the use of HWI as a recovery modality for sport. Although not directly related to recovery, research examining HWI has shown to result in increased heart rate, cardiac output, tissue temperatures and vasodilatation thereby increasing oxygen and antibody supply to the previously exercised muscles\textsuperscript{66, 75}. In addition, a decrease in muscle spasm and stiffness associated with HWI could provide post-exercise benefits for athletes\textsuperscript{38}.

In an attempt to promote the benefits of HWI and CWI, many athletes and sporting teams have begun using CWT; alternating between hot and cold water whole body immersion, as their chosen recovery modality\textsuperscript{30, 32, 75}. For example, of 39 elite New Zealand sporting teams 79\% used CWT on a regular basis with 100\% of the nine elite netball teams utilising this modality\textsuperscript{39}. The precise mechanism by which CWT improves recovery remains equivocal\textsuperscript{76}. The benefits associated with CWT include improved sprint and time trial cycling performance\textsuperscript{78} and improved self reported perceptual recovery through decreases in rate of perceived exertion (RPE) and muscle soreness\textsuperscript{42}. Additionally, CWT has been shown to reduce localised oedema and improve the rapid restoration of dynamic power and isometric force in individuals after the completion of a delayed onset muscle soreness (DOMS) inducing leg press protocol\textsuperscript{75}. Furthermore, Gill et al.\textsuperscript{30} examined the influence of CWT therapy on 23 male rugby players after four competitive matches and observed enhanced creatine kinase clearance when compared to a passive recovery\textsuperscript{30}. Although popular, many athletes cannot use CWT as a recovery modality due to an
inability to access the necessary facilities thus, there is a need for a recovery modality that allows easy exposure to hot and cold water.

The use of CS allows athletes to be exposed to both hot and cold water using facilities that are commonly available at sporting venues. To the authors knowledge no studies have examined the recovery benefits of CS in sport, however, scarce research examining the influence of cold shower exposure on physiological variables in a medical setting has provided promising evidence for its use as a recovery modality. Cold shower exposure has been shown to increase the production of beta endorphins thus increasing a sense of well-being and suppressing pain perception. Additionally, CS have been shown to activate components of the reticular activating system (raphe nuclei and locus ceruleus) resulting in an increased capacity of the central nervous system (CNS) to recruit motor neurons, thus providing a possible enhancement to muscular contractile function. A decrease in heart rate has been observed after cold shower exposure, and psychologically, cold showers have been used as a treatment modality for depression and chronic fatigue syndrome. While there are no studies to date specifically using hot showers as a recovery modality, hot showers have been utilised throughout numerous CWT studies as a substitute for HWI. Despite CS negating the hydrostatic influence of total water immersion, temperature must play an integral role in the recovery process, with studies suggesting CWI and CWT to be more beneficial than HWI.

As previously noted, many team sports (including netball) currently use water therapies following training and competition to enhance recovery. Netball is a fast moving team sport that places high physical demands on players through repeated rapid accelerations and decelerations, explosive jumps and muscle damage from eccentric loading. A netball game is played over a duration of 60 minutes
(15 minute quarters) consisting of high intensity exercise with intermittent sprint activity similar to that of basketball\textsuperscript{32, 42}. It is typical for elite netballers to train one or more times per day on all if not most days of the week and on occasions compete multiple times per day during tournament style competitions\textsuperscript{78}. Due to the large physiological demands placed upon the cardiovascular, metabolic, immune and musculoskeletal systems\textsuperscript{38, 42} during netball competition and training, it is essential to maximise post-training recovery to avoid the deleterious muscular and cardiovascular effects of fatigue\textsuperscript{60}. For these reasons, evidence based research is needed to examine the efficacy of CWT and CS as a recovery modality in elite level team sports.

1.2 PURPOSE STATEMENT/SIGNIFICANCE OF RESEARCH

Contrast water therapy has shown to improve recovery resulting in the maintenance of performance\textsuperscript{37, 45, 75, 77, 78}, however, despite widespread use; to date there is no published research that highlights the efficacy of CS as a recovery modality in individual or team sport\textsuperscript{25}. Contrast showers are a more convenient alternative to full body immersion therefore there is a need for research examining the influence of CS which would provide benefits to both sports scientists and athletes alike. The majority of studies examining recovery modalities have induced fatigue and muscle damage using eccentric exercises rather than realistic athletic scenarios simulating dynamic multi joint patterns typically seen in team sports\textsuperscript{9, 22, 26}. Additionally few studies have used elite athlete populations\textsuperscript{8, 22, 30, 56}. For these reasons, evidence based research is needed to examine the efficacy of CWT and CS in simulated team sport, more specifically in elite level team sport (i.e. netball).
1.3 RESEARCH QUESTION/S

1. Do CWT and CS provide adequate recovery of performance (i.e. repeated vertical jump and repeated agility) in elite female netballers, when compared with passive sitting?

2. Do CS provide similar cooling effects (decreased skin and core temperature) when compared to CWT? And do both methods provide superior cooling to a control condition?

3. Do athletes perceived CS to provide a similar level of recovery compared with CWT?

1.4 HYPOTHESES

The following hypotheses are proposed:

1. CS and CWT will provide adequate recovery for female netballers as seen by an accelerated restoration of performance to pre-exercise levels for the repeated vertical jump and repeated agility performance tests.

2. CS will provide similar cooling effects (skin and core temperature) as CWT via a reduction in skin and core temperature when compared to a control condition.

3. Athletes will perceive CWT and CS to be effective recovery modalities when compared to a control condition.

1.5 LIMITATIONS/DELIMITATIONS

The researcher acknowledges this research has limitations as followed:
1. The small sample size due to the availability of Australian elite level netball players.

2. All participants were asked to give full effort during all exercise and testing session; however, this cannot be guaranteed.

3. Due to the applied nature of this study and the high level of players selected measures needed to be as non-invasive as possible and could not be disruptive to the program therefore there was a limitation on what was measured and tested.

4. The researcher could not influence environmental conditions during the two week testing period that could have impacted core temperature post-exercise prior to recovery. This is because participants were required to walk between the netball courts and recovery centre that was open to the elements.

5. Extrinsic factors such as Australian coaches being present at some testing sessions could not be avoided and may have influenced performance results.

6. It was not possible to blind the participants to the recovery interventions.

The researcher acknowledges the following delimitations:

1. All findings are only applicable to elite level netball players.

2. All findings will only be applicable to women.
CHAPTER TWO: CRITICAL REVIEW OF LITERATURE

2.1 OVERVIEW

Recovery is an important component of an athlete’s training regime that is becoming increasingly popular among a variety of sporting codes. The increase of professionalism in sport has allowed elite athletes to focus purely on training and competition. As a result of this, coaches and athletes search for benefits that increase performances, one of which is post-exercise recovery. During periods of increased training volumes or intensities and tournament style competitions there may be inadequate time for athletes to recover naturally to an optimal state before the next exercise bout or session. The use of scientifically established recovery modalities during such circumstances may offer a competitive advantage for athletes, enabling the restoration of physiological and psychological parameters. Adequate recovery can decrease fatigue, accelerate the rate of physiological regeneration, replenish the bodies energy stores and reduce the risk of injury. Despite widespread use and obvious popularity of recovery sessions in sport, recent review articles have highlighted the scarce information pertaining to optimal treatment protocols and lack of quality scientific evidence for various recovery interventions. Most practitioners and athletes therefore follow anecdotal guidelines and reports.

With the increased use of recovery in professional sport, specifically the use of hydrotherapy, there is a need to execute quality scientific trials focused on specific components of recovery such as timing, modalities, performance and physiological mechanisms. This literature review will highlight specific areas of recovery, in
particular exploring the components and effectiveness of CWT and its convenient alternative CS, on elite athletes in team sports, in particular netball players.

2.2 PHYSICAL DEMANDS OF NETBALL

In team sports great importance is placed on training that is often physically demanding. The specific physiological and psychological demands encountered by athletes are important to identify to understand the sport, and to quantify the necessary recovery to prevent decreases in performance. In team sports such as netball with long competitive seasons, the ability to maintain fitness and performance is critical to a team’s success. Netball is a fast moving ball sport commonly played competitively by females for 60 minutes involving four 15 minute quarters. There are seven individual positions on a court made up of defenders, centre court players and attackers. The game is played on a court 15.25 metres by 30.5 metres with the length being divided into thirds. Players with an attack or defence in their position title are permitted in two consecutive thirds whereas goal shooters and keepers are only permitted in one third of the court. During a game movements occur over a short distance and are explosive in nature such as repeated short runs, jumps and sudden changes in direction. Despite netball’s widespread popularity, research into the physiological demands and movement patterns is lacking.

Much of the physiological information regarding netball has been derived from other intermittent sports such as soccer, basketball, rugby and hockey. Nevertheless, caution is needed when comparing netball to other sporting codes due to positional court restrictions. Few studies exist that have examined the physiological requirements of netball. Davidson and Trewartha analysed
movement patterns and physiological demands from three netball playing positions; centre court (C), attacker (GS) and defender (GK) over three English super league matches and observed a mean sprint duration during a game of 1.4 ± 0.4 seconds. These findings indicate the phosphocreatine system (short term energy system) plays an important role during a netball game. In comparison, greater mean sprint durations have been observed in hockey (1.8 ± 0.4 seconds) and Australian Football League (AFL) (2.4 seconds). Additionally, analysis of work to rest ratios (W:R) in netball indicate the high physical demands of this sport. During a game of netball a W:R ratio of 1:3 is common with a shorter 1:2 ratio observed in centre court players. These findings suggest an inability of individuals to obtain full energy system recovery (e.g. replenishment of creatine phosphate, adenosinetriphosphate (ATP) stores and the removal of lactate accumulation). For comparison purposes basketball and soccer have W:R ratios of 1:9 and 1:8 respectively.

In addition to the work and rest demands of netball, the stochastic nature of netball can provide further physical demands on players. During netball games, players often change both the mode (i.e. running and walking) and direction of activity. For instance, Davidson and Trewartha observed an activity change every 4.1 seconds with centre court players changing activity mode every 2.8 seconds. The constant change in direction and mode by players place high physical demands upon the body and an increased energy cost due to an elevated energy expenditure during backward and sideways movements. After intense exercise, such as a netball game, the internal milieu of the body is disrupted due to the nature of the activity undertaken which may result in decreased blood glucose concentrations, muscle glycogen levels and inflammation.
Despite limited information, it is evidently clear that netball is a team sport characterised by high physical demands through repeated explosive jumps, accelerations and decelerations. Therefore, it becomes imperative that effective recovery modalities are utilised to enhance recovery after physically demanding matches and training sessions to prevent injury, overtraining and inadequate performances\(^57\).

2.3 RECOVERY MODALITIES

There are numerous forms of recovery utilised by sporting teams in order to restore physical function post-exercise. Such recovery strategies include but are not limited to active\(^17, 59\), passive\(^17, 59\), hydrotherapy\(^59, 77\), massage\(^6, 17, 77\), stretching\(^76, 80\), hydration\(^6\), sleep\(^76, 80\), nutritional\(^6, 80\) and psychological recovery methods\(^80\). Furthermore, in some instances no formal recovery methods are used and thus athletes must self-monitor their recovery\(^6\). Innovation in the commercial sector has resulted in additional recovery products such as humidification therapy and compression garments\(^6, 29\). Although not universally accepted\(^43, 56\), the use of recovery interventions after exercise can decrease muscle soreness\(^29, 40, 42, 43, 78\) and in some instances result in the restoration of power\(^75, 77\), speed\(^37, 40\) and flexibility\(^45\). To date there is no consensus on the most effective recovery modality to provide the above benefits; however, within literature and the sporting environment the use of hydrotherapy as a viable recovery modality is quickly gaining acceptance\(^76\).

2.3.1 Water Immersion/Hydrotherapy

Hydrotherapy involves submerging all or parts of an individual’s body in water creating a pressure gradient against the body known as hydrostatic pressure.
Hydrostatic pressure is thought to create numerous physiological changes to the body such as creating a fluid displacement from the periphery to the central cavity, increasing substrate transport and reducing peripheral resistance\textsuperscript{77}. Additionally, water immersion creates an antigravity effect due to the water buoyancy that may decrease fatigue perceptions\textsuperscript{80}. The exact physiological mechanisms associated with hydrotherapy are poorly understood, however, numerous studies provide potential explanations. Hydrotherapy mechanisms that have been reported to enhance recovery include; muscle temperature and tissue changes\textsuperscript{38, 66, 81}, reduced rate of chemical reactions\textsuperscript{38, 40}, reduced demand for ATP\textsuperscript{76}, reduced oxygen requirements\textsuperscript{76}, blood flow changes\textsuperscript{38, 40, 76}, diminished stretch reflex responses to elongation\textsuperscript{66, 81}, reduced inflammation\textsuperscript{38, 66, 76, 81}, analgesic effects\textsuperscript{45}, reduced neural transmission\textsuperscript{38, 40}, decreased fatigue perception\textsuperscript{38, 43}, increased relaxation\textsuperscript{66} and decreased blood lactate\textsuperscript{17, 33, 66, 81}.

In comparison with traditional recovery methodologies such as active recovery, hydrotherapy has been observed to provide similar benefits such as an increase in blood lactate removal and blood flow without the need to expend extra energy\textsuperscript{80}. As lactate is acknowledged as a metabolite that contributes to muscular fatigue during intense exercise, its removal is deemed a benefit to recovery\textsuperscript{48}. Furthermore, the passive nature of hydrotherapy appeals to athletes, as seen through increase usage of hydrotherapy as a recovery modality\textsuperscript{76}. In addition to the importance of the hydrostatic forces during hydrotherapy, the water temperatures that the body is exposed to are also believed to be important\textsuperscript{76}. There are four known types of hydrotherapy that differ between temperature which can be performed; CWI, HWI, CWT and thermo neutral immersion.
2.3.2 Cold Water Immersion

Cold water immersion is defined as the immersion of the body in temperatures of less than 15°C\textsuperscript{81}. It is the most frequently used strategy for the treatment of soft tissue injuries commonly seen in the sporting field due to its ability to reduce inflammation, pain and spasm\textsuperscript{76}. Additionally, CWI is used for the treatment of numerous disorders such as arthritis, fibromyalgia and ankylosing spondylitis due to its analgesic and reduced inflammatory effects\textsuperscript{3}. Cold water immersion time and duration in sports research and in the sporting field varies. In the field, immersion may last up to as little as 30 seconds and in research up to 20 minutes\textsuperscript{81}. The inconsistency in immersion exposure times and the number of treatments is therefore a limitation when examining the mechanisms and comparing the influence of CWI on subsequent performance\textsuperscript{2}.

The application of CWI after team sport performance can offer valuable benefits to a coach such as reduce muscle soreness and restore repeat sprint ability and leg strength\textsuperscript{40}. A number of physiological changes occur through the cooling effect CWI has on the body. Immersion in cold water results in the withdrawal of heat from the body thereby decreasing skin and muscle temperatures\textsuperscript{68}. Cutaneous receptors are consequently stimulated causing fibres to vasoconstrict thus, decreasing metabolic rate which in turn lessens the inflammatory response and the formation of oedema\textsuperscript{16, 46, 66}. Additional physiological changes occur such as slowing of nerve conduction velocity, reduce cell necrosis and neutrophil migration, reduced cardiac output and heart rate and decreased blood flow\textsuperscript{7, 11, 38, 66}. As prompt recovery from muscle injury and damage is of primary concern for coaches, physicians and athletes it is suggested that CWI recovery modalities are likely to benefit\textsuperscript{3}.
Evidence regarding the efficacy of CWI are inconclusive with reports of both improved or maintained performances\(^1, 46, 75\) as well as reduced exercise performances\(^20,68\). These inconsistencies of findings are possibly due to the various methodologies used to examine CWI. For instance, a number of studies have examined the influence of CWI on athletes exercising in temperate environmental temperatures\(^1, 46, 75\) while others used more thermally hostile temperatures\(^51, 52, 82\). In addition, the majority of CWI studies have been conducted using unaccustomed exercise, muscle damage protocols or recovery following injury. This results in a limitation for recommendations of CWI following more dynamic whole body exercise seen in sport settings, which is more applicable for athletes and teams\(^1, 47, 76\).

A study by Vaile et al.\(^75\) induced muscle damage in strength trained males following a DOMS inducing leg press protocol in normal temperature conditions. The recovery interventions were; CWI (14 minutes at 15°C), HWI (14 minutes at 38°C), CWT (alternating 38°C for 1 minute; 15°C for 1 minute, 7 cycles) and control (seated rest) with measures of weighted squat jumps, isometric squats, perceived pain, thigh girths and blood variables. Findings from this study concluded that CWI improved recovery of isometric force, significantly enhanced squat jump performance and reduced the degree of thigh swelling, when compared to a control condition\(^75\). Furthermore, a study of 20 healthy men found that after a bout of strenuous intermittent shuttle running CWI (10°C; 10 minutes) diminished muscle soreness perception and lowered the decrement in maximal voluntary isometric contraction knee flexion using an isokinetic dynamometer\(^1\). In a randomised controlled trial Lane and Wegner\(^46\) investigated the effects of CWI on repeated bouts of high intensity cycling separated by 24 hours. Following 18 minutes of intermittent cycling at varying work intervals with a resistance of 80g/kg of body weight, ten
physically active men performed an active recovery, massage, control or CWI (15 minutes at 15°C) before another successive cycling interval. The results found that CWI facilitated recovery through the ability to maintain power output during consecutive intermittent cycling sessions separated by 24 hours when compared to a control condition\textsuperscript{46}.

The majority of research examining the use of CWI as a recovery modality after exercise in the heat provides support for this modality. Peiffer et al.\textsuperscript{52} examined the influence of a CWI (14°C; 5 minutes) recovery modality on repeated cycling performance in the heat and observed significantly better repeated 4 kilometre cycling performance after CWI compared with a control condition. Furthermore, compared with ice immersion and a control condition, CWI (14°C; 12 minutes) has been shown to enhance subsequent 2 mile run performance after a 90 minute bout of trail running in the heat\textsuperscript{82}. In this study, core temperature in both the CWI and ice water immersion conditions were lower post immersion and post race compared to the control treatment\textsuperscript{82}.

In contrast to the reports on beneficial effects of CWI on subsequent athletic performance in both hot and temperate conditions, not all research supports its use. Crowe et al.\textsuperscript{20} examined 17 active subjects who participated in two 30-second maximal cycling efforts separated by a one-hour recovery period, followed by either passive rest or a 15 minute CWI (13–14°C) recovery protocol. Peak power and total work were significantly decreased (1.1W kg\(^{-1}\); 13.1J kg\(^{-1}\), respectively) in sprint cycle performance following CWI recovery between cycling efforts\textsuperscript{20}. These authors concluded that caution should be used when implementing CWI between short exercise rest periods\textsuperscript{76}.
2.3.3 Hot Water Immersion

Hot water immersion (HWI), which involves submersion in water greater than 37°C, has been shown to improve recovery of performance between successive training sessions. This temperature exposes muscles to heat (thermotherapy) which increases tissue temperature, muscle elasticity, metabolic activity, peripheral vasodilation and reduces muscle spasm. Hot water immersion is commonly used to assist with rehabilitation of soft tissue injuries and athlete recovery by reducing muscle damage resulting from either competition or training loads. Studies into the efficacy of HWI are rare and contradictory. The available research claims superficial heat applied to the body such as HWI may increase joint extensibility, improve reaction time and produce analgesic effects. For instance, Skurvydas et al. proposed that HWI (44°C; 45 minutes) may increase the extensibility of the musculotendinous unit and create smooth contractions. Furthermore, Viitasalo et al. examined the use of HWI (underwater jet massage treatments) in 14 track and field athletes after participating in five strength/power training sessions over three days and observed an increase in continuous jump contact time and a reduction in power between repeated efforts after HWI compared with a control condition. It was concluded from this study that HWI can reduce DOMS and thus enhance/maintain performance.

It should be noted that HWI is not only performed in hot water baths/spas it is also commonly administered through hot showers in numerous CWT protocols. Additionally, compared to CWI literature and information pertaining to the use of HWI as a recovery modality is scarce thus, more evidence based research examining this recovery modality is required.
2.3.4 Contrast Water Therapy

Contrast Water Therapy combines the application of both HWI and CWI through repeated alternation of each modality and has become one of the most common post-exercise recovery modalities among elite athletes\textsuperscript{16}. Specifically, the use of this recovery modality in netball is popular particularly between games\textsuperscript{32}. Despite CWT being a popular recovery modality the mechanisms and scientific parameters such as temperature, total treatment time, sequence order and hot and cold application time remain unclear\textsuperscript{31, 49, 50}. One standard treatment protocol has therefore not been established\textsuperscript{50}. Protocols can range from alternating between hot and cold immersion for 30 seconds up to 10 minutes whilst immersion periods may be repeated one to five times\textsuperscript{29, 78}. Netball New Zealand anecdotally recommends that during the course of a tournament players should perform CWT for 5 minutes to aid recovery and performance\textsuperscript{81}. Immersion can vary from either starting or ending with hot or cold. In sports medicine it generally has been advised to start with hot immersion and end with cold to minimise the risk of oedema formation which may occur from finishing in the hot\textsuperscript{50}. Immersion temperatures also differ with hot and cold ranging from 34 to 44°C and 7 to 20°C, respectively\textsuperscript{50, 78}. The differing CWT recovery protocols are highlighted in Table 1 as well as the exercise protocols used and the findings of each study.
<table>
<thead>
<tr>
<th>Author</th>
<th>Temperature</th>
<th>Application</th>
<th>Time</th>
<th>Order</th>
<th>Immersion Method</th>
<th>Immersion Level</th>
<th>Recovery Interventions</th>
<th>Gender, Level and Sport</th>
<th>Subject Number</th>
<th>Exercise Protocol</th>
<th>Outcome Measures</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonham et al.</td>
<td>38-40</td>
<td>8-10</td>
<td>3min</td>
<td>30sec</td>
<td>Hot Immersion</td>
<td></td>
<td>CWT and passive recovery (PAS)</td>
<td>F, elite netball players</td>
<td>5</td>
<td>Metabolic beep test</td>
<td>Vertical Jump 505 Agility 5 and 10m sprints Heart Rate and RPE</td>
<td>CWT: Improved athletes perception of subsequent exertion</td>
</tr>
<tr>
<td>Coffey et al. (2004)</td>
<td>42</td>
<td>10</td>
<td>2min</td>
<td>1min</td>
<td>Cold Plastic Container Anterior superior iliac spine</td>
<td></td>
<td>CWT, Active, PAS</td>
<td>M, active, runners, multi-sport, recreational</td>
<td>14</td>
<td>Treadmill (runs to exhaustion at 120% and 90% of peak running speed).</td>
<td>Heart Rate Lactate Concentration RPE Treadmill exhaustion time Vertical Jump Sit and reach flexibility 6sec cycling sprint Muscle Soreness scale Intervention order of preference Counter Movement Jump (CMJ) Repeat CMJ 15sec 10 and 30m sprints M Agility Muscle Soreness visual analogue scale (VAS) 5RM squat</td>
<td>No significant performance differences. Increased perception of CWT recovery compared with PAS and active. No significant differences in performance measures between intervention groups. Participant’s intervention order of preference was Pool walking, stretching, CWT followed by CON. No significant differences in performance. CWT: lowered muscle soreness 1hour post-exercise when compared with PAS</td>
</tr>
<tr>
<td>Dawson et al. (2005)</td>
<td>45</td>
<td>12</td>
<td>2min</td>
<td>1min</td>
<td>Hot Cold Ice bath (cold) Standing waist deep shower (hot)</td>
<td></td>
<td>CWT, PAS, Stretching, Pool walking</td>
<td>M, Semi professional AFL players</td>
<td>17</td>
<td>AFL Game</td>
<td></td>
<td></td>
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<tr>
<td>French et al. (2008)</td>
<td>37-40</td>
<td>8-10</td>
<td>1min</td>
<td>3min</td>
<td>Cold Pool Seated upright in bath depth of 50cm</td>
<td></td>
<td>CWT, compression garments, PAS</td>
<td>M, recreational to regional, soccer and rugby players</td>
<td>26</td>
<td>exercise induced muscle damage (6 sets of 10 squats at 100% body mass and 1 eccentric squat at 1RM).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authors</td>
<td>Year</td>
<td>Week</td>
<td>Time</td>
<td>Type</td>
<td>Water Immersion</td>
<td>Water Temperature</td>
<td>Condition</td>
<td>Muscles/Effects</td>
<td>Protocol Description</td>
<td>Results</td>
<td></td>
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<td>Gill, Beaven and Cook (2006)</td>
<td>40-42</td>
<td>8-10</td>
<td>2min</td>
<td>1min</td>
<td>Cold and Hot Water Baths</td>
<td>Anterior superior iliac Spine</td>
<td>CWT, PAS, active, compression</td>
<td>M, elite rugby union players</td>
<td>Rugby Union Match</td>
<td>Creatine Kinase</td>
<td>Increased creatine kinase clearance for CWT, active and compression garments compared to PAS</td>
<td></td>
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<tr>
<td>Hamlin (2007)</td>
<td>38</td>
<td>8-10</td>
<td>1min</td>
<td>1min</td>
<td>Cold and Hot Plastic Container (cold) and Hot Shower (hot)</td>
<td>Hip height (cold) shower directed on legs (hot)</td>
<td>CWT and active</td>
<td>M &amp; F rugby players</td>
<td>20</td>
<td>Repeat sprint test (10 x 40 m sprints on 30s) repeated 60min later.</td>
<td>Lactate concentration and Heart rate</td>
<td>Repeat sprint test</td>
</tr>
<tr>
<td>Hamlin (2007)b</td>
<td>38</td>
<td>8-10</td>
<td>1min</td>
<td>1min</td>
<td>Cold and Hot Pool (cold) and Hot Shower (hot)</td>
<td>Leg and Hip height immersion (cold) and hot shower directed on legs (hot)</td>
<td>CWT, CWI and PAS</td>
<td>F, netball players</td>
<td>24</td>
<td>20m multistage fitness test followed by a repeat sprint test (6 x 5,10, and 15m sprint shuttles on 30s).</td>
<td>Lactate concentration of fatigue</td>
<td>Repeat sprint test</td>
</tr>
<tr>
<td>Higgins et al. (2009)</td>
<td>38-40</td>
<td>10-12</td>
<td>1min</td>
<td>1min</td>
<td>Cold and Hot Pool Immersion</td>
<td>Above the waistline</td>
<td>CWT, CWI and PAS</td>
<td>M, colts rugby union team</td>
<td>1 rugby union competition game and 2 training sessions per week for 4 weeks</td>
<td>Phosphate decrement test (7 all out sprints for 7sec with 21sec recovery) + 300m sprint test</td>
<td>CWT: benefits in recovery in rugby indicated by improved 300m sprint test performance post recovery compared with PAS.</td>
<td></td>
</tr>
<tr>
<td>Ingram et al. (2008)</td>
<td>40</td>
<td>10</td>
<td>2min</td>
<td>2min</td>
<td>Cold and Hot Pool Immersion</td>
<td>Level of umbilicus</td>
<td>CWT, CWI and PAS</td>
<td>M, team game experience</td>
<td>11</td>
<td>80 min simulated team sport exercise + 20m shuttle run test</td>
<td>Leg extension, leg flexion, and hip flexion maximal isometric strength Haemoglobin concentration. Total sprint time (10x20m) 20m sprint time Muscle soreness</td>
<td>RPE</td>
</tr>
<tr>
<td>King and Duffield</td>
<td>39</td>
<td>10</td>
<td>2min</td>
<td>1min</td>
<td>Cold and Hot Pool Immersion</td>
<td>Iliac crest</td>
<td>CWT, CWI, active, PAS</td>
<td>F, netball, recreational</td>
<td>10</td>
<td>4 x 15minute intermittent sprint</td>
<td>Repeat countermovement jump</td>
<td>Lowered RPE and muscle soreness after CWT and CWI compared to</td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Duration (minutes)</td>
<td>Time Difference (minutes)</td>
<td>Water Temperature</td>
<td>Exercise Circuit</td>
<td>Performance Changes</td>
<td></td>
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<tr>
<td>2009</td>
<td>Kinugasa and Kilding</td>
<td>38</td>
<td>12</td>
<td>Cold Pool</td>
<td>M, youth soccer players, sports academy</td>
<td>No significant differences in performance between recovery interventions. CWT: lowered lactate concentration when compared to active.</td>
<td></td>
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<tr>
<td>2009</td>
<td>Kuligowski et al. (1998)</td>
<td>38.9</td>
<td>12</td>
<td>Cold Whirlpool</td>
<td>M, physically active</td>
<td>No performance differences found between recovery interventions. CWT: lower tympanic temperature, thermal sensations and leg heaviness post intervention compared with stretching.</td>
<td></td>
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<td>2007</td>
<td>Morton</td>
<td>36</td>
<td>12</td>
<td>Hot Water Baths</td>
<td>M &amp; F, moderate exercise</td>
<td>CWT and cold whirlpool returned arm perceived soreness and elbow ROM values to baseline levels faster when compared to PAS and hot whirlpool.</td>
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<tr>
<td>2009</td>
<td>Robey et al.</td>
<td>40</td>
<td>12</td>
<td>Cold Water Bath</td>
<td>M &amp; F, club &amp; elite junior rower</td>
<td>No significant strength or performance differences existed between the recovery treatments.</td>
<td></td>
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<tr>
<td>1996</td>
<td>Sanders</td>
<td>38</td>
<td>15</td>
<td>Hot -</td>
<td>M, U/18 state field hockey squad</td>
<td>CWT: lowered fatigue at all time points with compared with PAS and active.</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Performance Parameters</th>
<th>Heart rate</th>
<th>Skin temperature</th>
<th>Lactate concentration</th>
<th>Muscle soreness</th>
<th>RPE</th>
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<tbody>
<tr>
<td>Kinugasa and Kilding</td>
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<td>Kuligowski et al.</td>
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<td>Morton</td>
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<tr>
<td>Robey et al.</td>
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<tr>
<td>Sanders</td>
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<tr>
<td>Study</td>
<td>Duration</td>
<td>Time</td>
<td>Temperature</td>
<td>Treatment</td>
<td>Participants</td>
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<tr>
<td>Vaile, Gill and Blazevich (2007)</td>
<td>40-42</td>
<td>8-10</td>
<td>Hot Cold Water Baths</td>
<td>CWT, PAS</td>
<td>M &amp; F, recreational athletes</td>
</tr>
<tr>
<td>Vaile, Halson, Gill and Dawson (2008)</td>
<td>38</td>
<td>15</td>
<td>Hot Cold Pool Immersion (ex head and neck)</td>
<td>CWT, PAS, CWI and HWI</td>
<td>M, Strength trained</td>
</tr>
<tr>
<td>Vaile, Halson, Gill and Dawson (2008)</td>
<td>38</td>
<td>15</td>
<td>Hot Cold Pool Immersion (ex head and neck)</td>
<td>CWT, PAS, CWI and HWI</td>
<td>M, Endurance trained cyclists</td>
</tr>
<tr>
<td>Versey, Halson and Dawson (2011)</td>
<td>38.4</td>
<td>14.6</td>
<td>Hot Cold Pool Immersion (ex head and neck)</td>
<td>CWT (6min, 12min, 18min) and PAS</td>
<td>M, Trained cyclists</td>
</tr>
</tbody>
</table>
In spite of the varying CWT protocols numerous research findings suggest CWT to be a promising recovery intervention for athletes by maintaining performance, reducing perceptions of fatigue and increasing lactate removal when compared to a passive modality\(^{32, 77}\). For instance, in 11 trained male cyclists following a 75 minute cycling protocol comprising of numerous sprints and time trials, the use of CWT (alternating 1 minute hot; 38°C, 1 minute cold; 15°C for either 6, 12 or 18 minutes) decreased whole body fatigue and muscle soreness when compared with a control condition\(^{78}\). Evidence further indicates that CWT can provide recovery benefits to non endurance athletes. Vaile et al.\(^{77}\) investigated the effects of two different recovery modalities; CWT (one minute cold (8-10°C) and two minutes hot (40-42°C) alternating five times to the level of the anterior superior iliac crest) and passive recovery following a DOMS inducing leg press protocol (5 x 10 eccentric bilateral leg press). A smaller reduction in power during jump squats and a faster reduction in symptoms of DOMS were observed after CWT compared with passive recovery\(^{77}\). Furthermore, in a more recent study by Vaile et al.\(^{75}\) the use of CWT (one minute hot and one minute cold full body immersion repeated seven times, for a total of 14 minutes) in recreational athletes after a muscle damaging protocol resulted in faster restoration of explosive athletic performance and strength compared with a control condition.

Not all research examining the effectiveness of CWT has produced beneficial results. Robey et al.\(^{56}\) found no significant differences in performance of leg strength or two kilometre rowing time following a stair run protocol when CWT (alternating 2 minutes hot; 40°C, 1 minute cold; 12°C repeated five times), control and stretching recoveries were employed\(^{56}\). Yet a major criticism of this study was the lack of fatigue induced by the exercise protocol\(^{31, 78}\). Nevertheless, Dawson et al.\(^{22}\)
monitored the post-game recovery benefits of CWT (alternating 2 minutes hot; 45°C, 1 minute cold; 12°C for five hot and four cold exposures), compression garments and passive sitting in 17 semi-professional male AFL players by utilising a pre and post game vertical jump and a six second cycling sprint. No performance differences between groups were observed. Following a 90 minute soccer match Kinugasa and Kilding found no performance differences (vertical jump) for 28 male youth soccer players following CWT (alternating 2 minutes hot; 38°C, 1 minute cold; 12°C repeated three times), stretching and a combined CWI and active recovery intervention. Furthermore, Coffey et al. found no significant performance differences in treadmill exhaustion time following CWT (alternating 2 minutes hot; 42°C, 1 minute cold; 10°C repeated five times), passive and active recovery for 14 highly active males. However, the authors noted an increase in recovery perceptions for CWT when compared to the other conditions. Numerous other studies have found no significant differences in performance when using CWT compared to a passive condition.

To date, only three studies have examined the effects of CWT on performance, physiological and psychological variables of netball players. In a crossover design Bonham et al. measured the recovery of performance (5 and 10 metre sprint time, agility and vertical jump) of five elite female netball players following a metabolic beep test when exposed to CWT (alternating 3 minutes hot; 38-40°C, 30 seconds cold; 8-10°C repeated three times finishing in hot) or control (passive sitting) recovery intervention. One hour following the recovery intervention the netballers were required to perform a second exercise bout (15 minute simulated netball circuit) incorporating 12 x vertical jumps, 8 x 5-0-5 agility tests, 4 x 5 metre sprints, 4 x 10 metre sprints and 11 treadmill runs. Results of the circuit indicate
after CWT rate of perceived exertion (RPE) was 1.6 units lower than passive and 4 x 5 metre speed was 0.26 seconds quicker (95% confidence limits, -0.71 to 0.18 seconds) than the passive trial. The authors concluded that CWT was a promising modality in limiting performance decrements and improving athlete perceptions when compared to a passive recovery. Nevertheless, this study failed to induce fatigue post-exercise and had a considerably small sample size of five thus; it is difficult to ascertain the true benefit of the recovery modality. In a second study, King and Duffield examined the influence of CWT compared with CWI, passive and active recovery on vertical jump, 20 metre sprint, 10 metre sprint and total circuit time in 10 recreational and regional netball players after a simulated netball circuit (4 x 15 minutes of intermittent sprint exercise). Additionally, RPE and muscle soreness were measured pre and post circuit and post recovery. No performance differences were observed between modalities; however, analysis of effect sizes indicated a trend towards a decline in sprint and vertical jump performance with both CWT and CWI. Conversely, significant decreases in muscle soreness and lower RPE values were observed in the CWT and CWI conditions compared with the two other modalities. Finally, Hamlin observed significantly faster blood lactate removal but no performance benefits for CWT (alternating 1 minute hot; 38°C, 1 minute cold; 8-10°C repeated three times) compared with CWI (alternating 1 minute seated cold water; 8-10°C, 1 minute standing out of water repeated three times) or a control condition in 24 female netball players who performed a 20 minute multistage fitness test followed by a repeat sprint test.

There is a paucity of research available to explain the mechanisms for which CWT can increase recovery. Regardless, several assumptions have been proposed to explain the effectiveness of CWT. It is possible that alternating between hot and cold
exposure creates a cycle of vasoconstriction and vasodilation of the blood vessels creating a type of pumping action, which in turn enhances lymphatic and venous flow\textsuperscript{19,27}. This postulation is used to explain the increased rate of removal of lactate and oedema following CWT\textsuperscript{81}. However, Fiscus et al.\textsuperscript{27} suggest this pumping action is not achievable as lymph capillaries do not have muscular walls and therefore cannot dilate and constrict disputing the previous prediction. Further benefits of CWT have been proposed (e.g. mild tissue temperature changes\textsuperscript{33}, increased blood flow\textsuperscript{33,78}, pain relief and stiffness\textsuperscript{78}, increased circulation in the contra-lateral extremities and reduced inflammation\textsuperscript{33,35,49,77}); however, these theories have yet to be validated.

2.3.5 Contrast Showers

Although CWT is commonly used among sporting teams\textsuperscript{16}, it may not always be readily available at sporting venues or when travelling. A convenient alternative to full body immersion is the use of shower facilities that can be alternated between hot and cold as a method of CWT; yet, negate the presence of hydrostatic pressure. Vaile et al.\textsuperscript{74} concluded that although hydrostatic pressure may contribute to the effectiveness of hydrotherapy as a recovery modality, temperature must also play an integral role as research findings have indicated CWT and CWI are more effective than HWI\textsuperscript{74,60}. This suggests that CS may be a promising recovery alternative to CWT. Despite widespread use and accessibility worldwide there is little information available on CS and their usage in sport. To our knowledge, the only published use of CS has occurred within the Indonesian Olympic Teams recovery checklist produced in the lead up to the 2008 Beijing Olympic Games. In this document, CS repeated 10 times was one of the recovery modalities suggested for use by Indonesian athletes\textsuperscript{6}. Numerous CWT protocols have utilised showers in
combination with immersion. For example a group of netballers performed CWT using hot showers for the heat component directed onto the legs combined with CWI. Findings from this study concluded lower post-exercise blood lactate when compared to a passive recovery\textsuperscript{32} and provided support for the use of showers as indicated by Vaile et al.\textsuperscript{74}.

Although showers have not commonly been prescribed in sport, cold showers have been utilised in a medical setting for the treatment of numerous conditions such as depression and chronic fatigue syndrome\textsuperscript{60, 61}. Depression is a disorder of the brain whereas chronic fatigue syndrome is characterised by reduced motor neuron transmission in the CNS that may increase fatigability of skeletal muscle\textsuperscript{60, 61}. Although the cause of depression and chronic fatigue syndrome is not well understood, it is thought that these conditions may arise due to a lack of exposure to physiological stressors commonly associated with frequent physical activity and changes in body temperature\textsuperscript{61}. The possible mechanism for which cold showers can help individuals with depression or chronic fatigue syndrome is through the delivery of a large scale stimulus to the body, in particular the brain\textsuperscript{61}. This stimulus is driven by contact with the cold as cold receptors within the skin are three to 10 times more dense than warm receptors thus, when simultaneously stimulated the response can be overwhelming for the brain resulting in a positive stressor\textsuperscript{61}.

Other physiological changes have been observed in humans exposed to cold showers. In particular, exposure to cold showers activates the reticular activating system (raphe nuclei and locus ceruleus) thus resulting in an increased capacity of the CNS to recruit motor neurons\textsuperscript{60}. Cold shower exposure can increase metabolic rate, which theoretically may result in accelerated recovery of muscle tissue from fatigue in chronic fatigue syndrome patients\textsuperscript{26, 60, 61}. This finding is especially
interesting in an athletic population as it indicates that cold showers could provide a recovery benefit to athletes\textsuperscript{26}. Plasma hormones such as beta endorphins and cortisol are increased due to cold shower exposure and cerebral synaptic release of noradrenalin is also noted\textsuperscript{26}. The effects of these hormones produce an increased sense of well-being and suppress pain through the increased opioid peptide beta endorphin that is an endogenous pain-killer\textsuperscript{26, 60, 61}. Together with accelerated muscle recovery these findings provide a strong rational for the use of cold showers as a post-exercise recovery modality. It should be noted that brief cold shower exposure appears to be safe and has no short or long term adverse effects on health\textsuperscript{60}.

The use of hydrotherapy as an effective recovery modality has received much attention over the last decade\textsuperscript{16, 38, 76}. Regardless of the effectiveness of CWI, HWI or CWT questions still remain as to the efficacy of these recovery techniques as the logistics surrounding their usage can limit their applicability in the field. The use of showers to deliver a hydrotherapy based recovery intervention are promising as this technique presents a more accessible option and, as presented above, can possibly provide similar physiological stimuli to CWI, HWI and CWT. Yet, due to the lack of research examining the use of showers in sport, research in this field is needed before coaches, athletes and/or sports scientist can be confident using this modality.

\section*{2.4 CONTRAST RECOVERY RESEARCH IN ELITE ATHLETES}

A great deal of the available recovery research, specifically research focused on hydrotherapy, has used recreational athletes\textsuperscript{17, 29, 37, 40, 45, 47, 48, 75}. Transposing findings from recreational athletes to those of elite athletes may be confounded by the unequal training volumes and competition demands placed on elite athletes compared with their recreational counterparts\textsuperscript{4}. Furthermore, the negative effects of
exercise, such as fatigue, are easier to induce in an untrained population compared with elite athletes, thus elite athletes are likely to respond differently to post-exercise recovery strategies compared with untrained individuals. In order to determine the most optimal recovery strategies for elite athletes, research must focus on this population. Of the 19 studies of CWT presented in Table 1, only five have recruited elite athletes (elite netball, elite rugby union, semi-professional AFL players, elite junior rowers, U/18 state hockey squad) whereas the other 14 have used recreational or development level athletes. This presents an area for future research.

2.5 PERFORMANCE AND RECOVERY IN FEMALE ATHLETES

Women are making significant contributions to Australian sport thus, it is essential that scientists continue to explore the effects that the female menstrual cycle has upon athletic performances. The menstrual cycle is a physiological phenomenon and although the belief is that the menstrual cycle decreases physical capacity and performance, many medal winning performances have been won during all phases of a menstrual cycle.

2.5.1 Female Menstrual Cycle and Performance

The female menstrual cycle is regulated by a combination of complex interactions of the hypothalamus, anterior pituitary gland, the ovaries, follicles and the corpus luteum. A normal menstrual cycle is said to have a length of 28 days but is highly variable between individuals and may range from 28 to 38 days each cycle. Throughout a menstrual cycle females are exposed to fluctuations in steroidal hormone levels which could have a potential impact on performance. The menstrual cycle may be regulated through taking an oral contraceptive, with the intention of
stabilising the cycle to ensure consistent performance through the stabilisation of hormones that otherwise fluctuate i.e. peptide and steroid hormones\textsuperscript{54}. Relevant stages to consider are pre-menstrual and menstrual, the follicular and luteal phases separated by an abrupt elevation in luteinizing hormone and characterised by a sharp rise in body temperature coinciding with ovulation\textsuperscript{54}.

Exercise performance and the menstrual cycle may interact in various ways to the extent that few experimental studies of female athletes are considered without controlling for menstrual cycle phase\textsuperscript{54}. Nevertheless, it is widely accepted in professional female sport that menses should not influence training or competition. Current literature suggests that fluctuations in female reproductive hormones through the menstrual cycle do not affect muscle contractile characteristics\textsuperscript{24}. Most research report no changes over the menstrual cycle for the many determinants of maximal oxygen consumption, such as lactate response to exercise, bodyweight, plasma volume, haemoglobin concentration, heart rate and ventilation\textsuperscript{24}. These findings suggest that regular menstruating female athletes, competing in strength-specific sports and intense anaerobic/aerobic sports such as netball, do not need to adjust for menstrual cycle phase to maximise performance\textsuperscript{24}. Of note, there is evidence that the menstrual cycle affects temperature regulation with an increased resting core temperature during the luteal phase accompanied by increased core temperature thresholds for thermoregulatory effectors responses\textsuperscript{24}, which is a consideration during testing in the present investigation.

2.6 SUMMARY
The high physical demands and short recovery durations between competition in netball results in the need for optimal recovery strategies to enhance training
adaptations and performance. Currently there is no consensus on the effectiveness of recovery modalities on daily performances despite a large array of accessible recovery modalities. One recovery modality which is escalating among sporting teams is hydrotherapy. Hydrotherapy is thought to provide similar benefits to an active recovery such as a decrease in blood lactate removal and an increase in blood flow without the need to expend extra energy. Hydrotherapy can be implemented in several ways (CWI, HWI, CWT, CS); yet, not all modalities are accessible thus, practical. For this reason, CS may provide the most practical recovery modality for most sporting teams and athletes. While research indicates that hydrotherapy may assist in recovery following exercise, no study has yet examined the effectiveness of CS as a recovery modality. Furthermore, the lack of scientific data examining recovery strategies in elite athletes and more specifically female elite athletes is severely lacking. For these reasons, the focus of this thesis will be to examine the use of CS and CWT as a viable recovery modality in elite women netball players.
CHAPTER THREE: METHODS

3.1 INTRODUCTION

The purpose of this research was to examine the effect of CS on elite female netballers following a netball specific exercise session. In particular, this study focused on the netballers’ performance, physiological (skin and core temperature) and psychological parameters, which was accomplished using the following research design.

3.2 STUDY DESIGN

A randomised/counterbalanced cross-over design was employed for the study with participants acting as their own control. The study was conducted over a four week period incorporating five separate visits to the Australian Institute of Sport (AIS) Recovery Centre in Canberra: two familiarisation sessions and three experimental testing sessions. All experimental sessions were separated by a minimum of two days with trials only differing in the recovery protocol. All testing was completed at a similar time of day to control for circadian variability. All participants completed similar training workloads between experimental sessions which were prescribed by coaching staff. Participants were given a food diary (Appendix 2) by a sports dietitian to record food and fluid intake consumption 24 hours prior to their first testing/exercise session and during the trial. For each subsequent trial, participants were instructed to repeat their dietary intake from the initial trial. Participants refrained from caffeine and alcohol ingestion throughout the duration of testing. All participants met pre-exercise guidelines (ACSM guidelines for pre-exercise) of 1-4g carbohydrate (CHO)/kg body weight prior to each session. Along
with the food diary participants were given a menstrual cycle questionnaire to complete (Appendix 7). Research has shown little effect of menstrual cycle on anaerobic/sprint performances, therefore there was little need to test athletes in the same stage of the menstrual cycle. However, throughout the testing sessions menstrual cycle was randomised.32

3.3 SAMPLING METHODOLOGY

Eleven AIS female netballers (mean ± SD; age: 20 ± 0.6 years, height: 182.0 ± 5.0 cm, body mass: 77.0 ± 9.3 kg and sum of seven skinfolds = 98.3 ± 27.1 mm) volunteered to participate in the study. One participant withdrew from the study due to injury. All participants were of elite calibre having represented Australia as players in Junior Australian Teams (U/19 and U/21 competitions) and were in the middle of pre-season games and training. A written description of the risks and benefits in this study was given to all participants and a signed informed consent was obtained before the start of data collection. Ethical approval for this study was obtained from the Murdoch University Human Ethics Committee and the AIS Research Ethics Committee (Appendix 1). The participants were familiar with all performance test protocols due to weekly physiology testing sessions and were regular users of the recovery techniques.

3.4 PROCEDURES

During the initial two laboratory visits (familiarisation sessions) participants were required to complete a netball specific circuit (see below) to become accustomed to the exercise requirements and reduce any learning effects. Participants mass, height
and skinfolds were also recorded at this time by a sports dietitian following the International Society for the Advancement of Kinanthropometry (ISAK) guidelines. Participants were then asked to complete three experimental sessions separated by no less than two days. Six hours prior to the start of each experimental session, participants were instructed to ingest a core body temperature sensor pill (HQ Inc., Florida, USA). The six hour ingestion time was standardised to ensure the pill was insensible to swallowed hot or cold liquids. Upon arriving at the netball courts participants were fitted with a heart rate monitor (Suunto Heart Rate Team Pack, Vantaa, Finland), skin temperature sensors in the form of iButtons (DS1922L Thermocron iButton, Embedded Data Systems, California) to five sites of the body; head, chest, arm, thigh and calf. Prior to the start of testing, participants were informed of the recovery modality (CWT, CS or PAS) they would be completing during that session and were asked to predict the effectiveness of the recovery modality using a visual analogue recovery scale. Additionally, participants were asked baseline levels for whole body fatigue, thermal sensations and RPE (Appendix 8). These three scales were recorded post testing, post-exercise circuit and post recovery. After completing the scale questionnaires, all players performed a standardised warm-up which was conducted before each testing session and prior to each post-recovery performance session outlined in Appendix 3. Following warm up, participants were asked to complete a series of performance measures (repeated agility and vertical jump), after which they began the simulated netball circuit (Figure 2.2). Immediately following the completion of the simulated netball circuit participants rated their RPE and performed a second performance testing session followed 20 minutes later by the designated recovery intervention. At the cessation of the recovery intervention (14 minutes) participants were asked to rate the
effectiveness of the current recovery modality using a visual analogue scale. Immediately following this participants returned to the netball courts to perform a post-recovery performance testing session (acute). The performance testing session was repeated at 4:00pm (delayed) and at 9:00am the next day (24 hours) along with the whole body fatigue scale (Figure 3.1). This particular protocol was selected as it replicates a typical training day for the particular group of AIS scholarship netballers. The participant order and the test administrator for each performance test were kept constant throughout all testing sessions to ensure identical rest periods.

**Figure 3.1: An outline of the study experimental design**

![Figure 3.1](image)

### 3.5 NETBALL SPECIFIC EXERCISE CIRCUIT

The netball specific circuit was modified from Higgins, Naughton and Burgess in collaboration with coaching staff and netball medical personnel at the AIS\(^36\). During the circuit verbal encouragement was provided by coaching and support staff to ensure maximal effort. Court marking tape remained fixed to the netball courts over
the duration of the study to ensure the same marks were used for each session. The modified circuit comprised of five stations spanning the length of the netball court in a line, each station separated by 3.5 metres. Running through each station over the length of the court and a jog back in 30 seconds was considered as one lap. The stations comprised of movements such as short explosive sprints, agility, backward and sideways movements and jumps interspersed with a series of fatiguing repeated sprints. A detailed account of the five stations is illustrated in Figure 3.2. Throughout the circuit a timekeeper was assigned to call out time and ensure all participants completed the circuit as designed. The completion of one circuit involved 5 laps of the stations in 2.5 minutes (30 seconds each lap) followed by 30 seconds to complete 5 maximal counter movement jumps (CMJ) repeated immediately one after another with the remainder of the time provided as rest. Following the 30 seconds recovery, two up and back sprints from baseline to baseline was completed in 24 seconds followed immediately by 10 chest passes at a wall using a netball. Five minutes was allocated to complete one circuit. The circuit was repeated twice more totalling three times (3 sets = 15 minutes). Appendix 4 illustrates the circuit layout on court and participants running through the circuit. Average and maximum heart rates were recorded throughout the circuit.
Figure 3.2: Outline and Description of the Netball Circuit Stations
(adapted from Higgins, Naughton and Burgess, 2009)

**Station 1**

Restart drill is designed to replicate movement patterns a player performs at centre restarts.

Player performs fast feet (double) through fast foot ladder (9), then a rapid sprint to either the left of right cone and turn and sprint to the other.

**Station 2**

The lead was designed to replicate the movement patterns a player performs when making a lead to receive a pass in a close marking situation.

Player begins with a zig zag run, changing direction rapidly, finishing with a sprint.

**Station 3**

Defend drill replicates the movement a player goes through at a centre restart, in a close marking situation, where opposition is in possession of the ball.

- **Black** arrow 3 m fwd sprint
- **Green** Line 1.5 m side shuffle
- **Red** arrow 2 m diagonal run
- **Blue** line 2.5 m backward run

**Station 4**

End third drill replicates movement patterns made by a player at the end third of the court, as an attacker or defender.

Multiple sideways shuffles replicate evasive action taken by player in close marking situation trying to break from opposition.

Short sprint followed by a quick dash sideways (either left or right)
3.6 RECOVERY INTERVENTIONS

Participants performed one of three recovery interventions:

- **Passive Recovery**: Participants remained seated with minimal movement for 14 minutes in a temperature controlled environment (20.0°C ± 0.7°C).

- **CWT**: Commenced in hot water (38.0°C ± 0.4°C) and alternated between hot and cold water immersion (15.0°C ± 0.3°C) every minute with a 5 second transfer time, to ensure maximal water exposure, for a total of 7 cycles. Figure 3.4 illustrates participants immersed in the cold water pool.

- **CS**: Participants alternated through a series of hot (38.0°C ± 1.2°C) and cold (18.0°C ± 0.4°C) showers, completing 7 x 1 minute bouts under each temperature, totalling 14 minutes. The coldest the shower temperature would drop, at the particular time of year, from the tap was 18°C without adding a cooling unit, therefore for practicality 18°C was used. Participants immersed their entire body including head under the shower. Figure 3.3 illustrates participants alternating through the CS.

The interventions were selected using similar protocols and temperatures to previous CWT research conducted at the AIS\textsuperscript{73,75,78} whilst CS protocols were adopted from the CWT protocol. At the end of the recovery period participants were instructed not to shower, just dry off with a towel and told not to partake in any extra activity that may impact results of the study.
Figure 3.3: Participants alternating through contrast showers

Figure 3.4: Participants immersed in cold water maintained at 15°C
3.7 PHYSIOLOGICAL MEASURES

Real time heart rate was recorded throughout all exercise sessions using a heart rate chest monitor fitted to each athlete. Maximum and average heart rates were recorded for the netball specific circuit to provide an indication on the intensity of the performed exercise. Heart rate has been documented as an indicator of circulatory strain during intermittent exercise/sports\textsuperscript{57}.

Core temperature ($T_{core}$) was measured in the intestine pre and post the exercise session, performance testing sessions and pre, post and 20 minutes post-recovery. During exercise, $T_{core}$ data was wirelessly transmitted to a Core Temperature Data Recorder (HQ Inc., Florida, USA) which convert the signal from the $T_{core}$ sensor into a digital format. All pills were calibrated and checked at three different temperatures against a certified mercury thermometer in a water bath prior to use.

Five site skin temperature values were recorded through the use of the iButton electronic sensors at a 5 second sampling rate and calculated with the following equation:

$$\bar{T}_{\text{skin}} = 0.3 \times (T_{\text{chest}} + T_{\text{arm}}) + 0.2 \times (T_{\text{thigh}} + T_{\text{leg}})^{53}$$

The iButton manufacturers report an accuracy of ±0.5°C from -10°C to 65°C, however, a study by Harper Smith et al.\textsuperscript{65} reported the iButton DS1992L to have a high validity with a correlation coefficient greater than .99 and a reliability of coefficient of variation less than 1%. Finally, a total body temperature equation was calculated according to the Burton\textsuperscript{13} equation using both the $T_{core}$ and $\bar{T}_{\text{skin}}$ values:

$$\bar{T}_{\text{body}} = (0.87 \times T_{\text{core}}) + (0.13 \times \bar{T}_{\text{skin}})$$
3.8 RECOVERY ASSESSMENT

3.8.1 Performance Measures

Performance recovery was assessed using the vertical jump and repeated agility tests. During the vertical jump tests, participants completed a series of four maximum jump trials (Yardstick, Swift Performance Equipment, Wacol, Australia) separated by 15 seconds. Maximal vertical jump height is a practical and commonly utilised test among many sports, in particular netball and soccer. Prior to each vertical jump testing session, participant standing reach height was recorded as the highest distance reached with participants extending their hand fully above the head with full elevation of the shoulder in the vertical plane, whilst both feet and heels remained in contact with the floor. After determining standing reach height, participants performed a CMJ. Participants were instructed to bend their knees to a freely chosen angle whilst using maximal arm swing and then perform a CMJ displacing as many plastic vanes from the yardstick as possible. Instructions were given to jump as high and explosively as possible. The distance from the ground to the furthest displaced vane, minus standing reach height, was used to calculate vertical jump height. The coefficient of variation of the vertical jump test measured on the particular group of participants was 2.6%.

Agility tests are commonly used in physical testing sessions to measure an athlete’s ability to accelerate, decelerate and change direction with speed. The participant group of netballers regularly use both the planned and repeated planned agility tests during weekly physical testing sessions. In the study, participants started from a stationary position and were required to weave in and out of a series of five poles 1.1 metres high placed 2.5 metres apart as per the diagram in Appendix 5. This was performed a total of four times with participants starting every 20 seconds.
recorded by a hand held stop watch. The total time of each trial was calculated and recorded in seconds by dual beam electronic timing gates (Speedlight TT, Swift Performance Equipment, Wacol, Australia). Participants were given verbal encouragement throughout each trial to ensure maximal effort. The planned agility test was used in the study as it has shown to be a highly reliable measurement on this participant group with a low coefficient of variation of 1.2% calculated from previous testing results.

3.8.2 Psychometric Measures

Three perceptual scales and two questionnaires were used during the study to assess participants fatigue levels, thermal sensations and perceptions of the effectiveness of each recovery modality pre and post recovery (Appendix 6). The three perceptual scales were:

1) rate of perceived exertion (RPE),
2) thermal sensations, and
3) whole body fatigue (Appendix 8).

Whilst the two questionnaires were a pre and post intervention questionnaire and a menstrual cycle questionnaire.

In order to measure the perceived intensity of each exercise session participants were immediately asked to rate their perceived exertion using a scale from 6 (no exertion) to 20 (maximal exertion) post-exercise. Borg’s 10-point Likert scale was used to measure whole body fatigue pre and post-exercise and recovery with 0 being nothing at all and 10 being extremely high. A thermal sensation scale was additionally utilised during the study pre and post-recovery using a Likert scale with 0 being unbearably cold and 8 being unbearably hot. To determine the participants’ thoughts on the efficacy of each recovery modality undertaken a pre
and post-intervention questionnaire was employed. For this questionnaire two questions were asked, one prior to recovery “Do you believe the post-exercise recovery modality will accelerate your recovery in this trial?” and the other was given after recovery “Do you believe the post-exercise recovery modality has accelerated your recovery in this trial?” Participants answered on an unmarked horizontal line (10cm in length) with strongly agree and strongly disagree at each end and neutral in the middle. The participants scores were then calculated based on the number of millimetres their ranking were placed from the “strongly agree” end of the scale.

3.9 STATISTICAL ANALYSIS

Differences in performance, psychological (whole body fatigue and thermal sensation) and physiological measures between conditions were determined using a two-way analysis of variance (ANOVA; condition x time) with repeated measures. Significant main events or interactions were analysed using a Tukey’s HSD post-hoc analysis. The Will and Has psychological variable was measured through a one-way ANOVA to test for differences among each of the three recovery interventions. A pre-post T-test was additionally conducted to test for the difference within each recovery intervention. Therefore, the three recovery interventions were assessed independently of one another. All, statistical analyses were conducted using a commercially available statistical software package (Statistica v 8, Rockaway, NJ) with the level of significance set to p ≤ 0.05. All data are presented as means ± standard deviations unless otherwise specified.
CHAPTER FOUR: RESULTS

4.1 CIRCUIT MEASURES

Table 2: Mean (± SD) heart rate and ratings of perceived exertion measured during the netball circuit for each recovery condition.

<table>
<thead>
<tr>
<th></th>
<th>PAS</th>
<th>CS</th>
<th>CWT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate (bpm)</td>
<td>182 ± 8</td>
<td>181 ± 7</td>
<td>180 ± 8</td>
</tr>
<tr>
<td>RPE</td>
<td>19 ± 1</td>
<td>18 ± 1</td>
<td>18 ± 2</td>
</tr>
</tbody>
</table>

CS= contrast showers. PAS= Passive recovery. CWT= contrast water therapy

Descriptive statistics for the netball specific circuit for each recovery intervention are shown in Table 2. Mean heart rate during the exercise circuit did not differ between the recovery conditions. Similarly, no statistical differences were observed between conditions for RPE during the exercise session.
**4.2 AGILITY PERFORMANCE**

A significant main effect for time was observed for the measure of agility \( F (15.76) = 4, p < .001 \). In all conditions, the mean time necessary to complete the agility test was greater post-exercise \((38.29 \pm 1.2)\) compared with all other time points (Figure 4.1).
4.3 JUMP PERFORMANCE

Figure 4.2 Vertical jump (mean ± SD) before the agility test (a) and after the agility test (b) measured at baseline, immediately post-exercise (PostEx), immediately after recovery (Acute), 5 hours post recovery (Delayed) and 24 hours post recovery (24h) in the contrast shower (●), contrast water therapy (■) and passive (▲) recovery intervention groups. * Indicates a main effect for time; significantly greater compared with all other measured points. ** Indicates a main time effect compared to post-exercise.

A significant main effect for time was observed for both the vertical jump (VJ) before the agility test [f (.001) = 12, p<.001] and the VJ after the agility test [f
(.018) = 4, p<.01] (Figure 4.2). In all conditions before the agility test, the mean distance jumped was greater post-exercise circuit (46.5 ± 5.3 cm) than all other time points (Figure 4.2a), and following the agility test VJ (Figure 4.2b) was significantly greater (p=.017) measured post-exercise (45.7 ± 6.1 cm) compared with 24 hours post recovery (44.3 ± 4.7 cm) values.
4.4 TEMPERATURE

Figure 4.3 Mean (± SD) changes in skin temperature ($T_{\text{skin}}$) (a), core temperature ($T_{\text{core}}$) (b) and mean body temperature ($T_{\text{mean}}$) (c) following CS (●), CWT (■) and PAS (▲) across time is documented. Data is representative of nine participants. * Indicates significant ($p<.05$) differences between both recovery interventions and PAS. # Indicates a significant ($p<.05$) difference between CS and CWT. ## Indicates a significant difference between PAS and CWT. + Indicates a main effect for time;
significantly different with all other measured points. ++ Indicates a main time effect compared to baseline. ** Indicates a significant difference between passive core temperature and other interventions.

A significant interaction was observed for T_{skim}, with greater T_{skim} measured at the end of recovery and 20 minutes post-recovery in the PAS (31.21 ± 1.09°C and 30.56 ± 0.79°C; respectively) compared with the CS (27.44 ± 1.53°C and 25.37 ± 1.67°C; respectively) and CWT (24.63 ± 2.28°C and 24.86 ± 1.43°C; respectively) conditions. In addition, T_{skim} is significantly greater in the CS compared with CWT at the end of recovery time point. Measurements of T_{core} displayed no significant differences between recovery interventions; however, a significant main effect for time is observed \[ t(54.0) = 5, \ p<.001 \] (Figure 4.3b). Core temperature was significantly greater post-exercise (39.07 ± 0.29°C) and at the start of recovery (38.39 ± 0.52°C) compared with all other time points. Additionally, T_{core} at the end of warm-up (37.96 ± 0.25°C; p=.003) and recovery (37.83 ± 0.41°C, p=.021) was significantly greater compared with baseline (37.42 ± 0.44°C). The percent difference between the end of recovery and 20 minute post recovery measure of T_{core} was significantly greater in CWT (-1.0%) and CS (-1.0%) compared with PAS (0.00%) condition. A significant interaction was observed between measurement time and recovery condition for T_{mean} \[ t(3.9) = 10, \ p<.001 \] (Figure 4.3c). At 20 minutes post-recovery T_{mean} for CS (36.00 ± 0.44°C) and CWT (35.83 ± 0.36°C) were significantly less compared with PAS (36.83 ± 0.48°C). At end of recovery T_{mean} was significantly less in the CWT (36.08 ± 0.25°C) compared with the PAS (36.95 ± 0.43°C) condition.
4.5 SUBJECTIVE MEASURES

Table 3 Mean (± SD) whole body fatigue, thermal sensation and Will and Has (perception of recovery) measures in contrast showers (CS), contrast water therapy (CWT) and the control condition (PAS) at all time points is presented.

<table>
<thead>
<tr>
<th></th>
<th>CS</th>
<th>PAS</th>
<th>CWT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Whole Body Fatigue</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>4 ± 1.2</td>
<td>4 ± 0.7</td>
<td>3 ± 0.8</td>
</tr>
<tr>
<td>Post Testing</td>
<td>5 ± 1.6</td>
<td>5 ± 0.9</td>
<td>4 ± 1.3</td>
</tr>
<tr>
<td>Post-exercise Circuit</td>
<td>8 ± 1.6</td>
<td>8 ± 1.2</td>
<td>7 ± 1.9</td>
</tr>
<tr>
<td>Post Recovery</td>
<td>4 ± 0.9</td>
<td>4 ± 1.0</td>
<td>4 ± 1.5</td>
</tr>
<tr>
<td>Delayed (5 hours)</td>
<td>5 ± 1.2</td>
<td>5 ± 1.1</td>
<td>4 ± 1.2</td>
</tr>
<tr>
<td>24 hours post-exercise</td>
<td>4 ± 1.3</td>
<td>4 ± 1.0</td>
<td>4 ± 1.1</td>
</tr>
<tr>
<td><strong>Thermal Sensation</strong></td>
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<tr>
<td>Baseline</td>
<td>4 ± 1.0</td>
<td>4 ± 0.8</td>
<td>4 ± 0.8</td>
</tr>
<tr>
<td>Post Testing</td>
<td>6 ± 1.0</td>
<td>6 ± 0.5</td>
<td>5 ± 0.8</td>
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<tr>
<td>Post Circuit</td>
<td>7 ± 0.5</td>
<td>7 ± 0.6</td>
<td>7 ± 0.8</td>
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<tr>
<td>Post Recovery</td>
<td>4 ± 0.7</td>
<td>4 ± 0.7</td>
<td>3 ± 1.0</td>
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<tr>
<td><strong>Will/Has Statement</strong></td>
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<tr>
<td>Will</td>
<td>46.70 ± 15.24</td>
<td>68.80 ± 11.21#</td>
<td>19.70 ± 14.71</td>
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<tr>
<td>Has</td>
<td>17.70 ± 12.98*</td>
<td>72.80 ± 14.26##</td>
<td>18.95 ± 13.77</td>
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</tbody>
</table>

CS= contrast showers. PAS= Passive recovery. CWT= contrast water therapy. * Significant main effect for time. * Significant difference between the will and has statements within condition. #Significant difference of the “will” statement between all conditions. ## Significant difference of the “has” statement between conditions (passive).

A significant main effect for time was observed for the subjective whole body fatigue measure \([f (58.99) = 5, p<.001]\). In all conditions, whole body fatigue was significantly greater post netball exercise circuit compared with all other time points (Table 3). A significant main effect for time was also observed for measures
of thermal sensation \( [f (88.57) = 3, p<.001] \). In all conditions, thermal sensations was significantly greater \((7 \pm 1.0)\) post netball exercise circuit compared with all other time points.

Mean perceptions of the effectiveness for each recovery modality before (Will) and after (Has) the recovery interventions are presented in Table 3. Perceived effectiveness (Will statement) was significantly greater in CWT \((19.70 \pm 14.71)\) compared with CS \((46.70 \pm 15.24)\) and the control \((68.80 \pm 11.21)\) conditions. After completing the recovery interventions, participants perceived CWT \((18.95 \pm 13.77)\) and CS \((17.70 \pm 12.98)\) to provide greater recovery benefits compared with the control condition \((72.80 \pm 14.26)\). A significant \((P<.001)\) change between Will and Has statements was observed in CS only.
CHAPTER FIVE: DISCUSSION

This study investigated the effects of CWT and CS compared to a control condition (passive recovery) on performance (vertical jump and repeated agility), physiological (skin and core temperature) and psychological (whole body fatigue, thermal and RPE) responses in elite netball players after a simulated netball circuit. The main findings from the study were that:

1) no significant differences were observed in repeated vertical jump or repeated agility performance at any time point between recovery conditions,
2) no differences in $T_{core}$ were found at any time points between conditions, however, a greater percent difference was observed from post-recovery to 20 minutes post-recovery in CWT and CS compared with passive recovery,
3) during and after the recovery intervention $T_{skin}$ was significantly lower in CWT and CS compared with passive recovery,
4) overall positive perceptions were observed in CWT and CS when compared with passive, and
5) participants perceptions of CS changed pre-post intervention significantly indicating an enhanced perception of the modality following the intervention.

Findings from the present study indicate that the application of CWT or CS after a 15 minute netball specific exercise circuit did not enhance recovery of performance as measured through repeated vertical jump and repeated agility performance trials. The lack of difference between conditions provides further support to research indicating a null effect of CWT on performance. The inability to induce a significant level of fatigue following exercise has previously been suggested as the reason for null CWT findings. In the current study;
however, the author indeed induced an adequate level of fatigue as measured by
significantly increased repeated agility times, greater RPE and whole body fatigue
scores post netball circuit thus, is confident the study results represent the true effect
of the selected recovery modalities. Nevertheless, the term recovery indicates a
return to baseline and while improved performance is appealing, the focus of a
recovery intervention should be returning athletic performance to a pre- exercise or
competition state\textsuperscript{14}. In the current study all conditions (CWT, CS and PAS) resulted
in the return of performance to baseline levels (Figure 4.1 and 4.2). Several other
factors may have had greater impact on the netballers recovery than the
interventions; young age, elite status, appropriate energy stores and hydration
levels\textsuperscript{18}. The current results demonstrate that although CWT and CS did not enhance
recovery compared to passive rest the recovery interventions employed were not
detrimental to a netballer’s simulated performance.

In contrast to this study’s findings, numerous studies have observed
performance benefits following CWT protocols\textsuperscript{8,37,40,74,75,77,78}. For instance, Vaile et
al.\textsuperscript{74}, using a similar CWT recovery protocol (alternating 1 minute hot; 38°C, 1
minute cold; 15°C) performed daily for four consecutive days observed significantly
better cycling performances compared to HWI and PAS. Specifically, cycling sprint
performance was enhanced at day two and cycling time trial performance was
enhanced at day four\textsuperscript{74}. It is suggested that recovery interventions may be more
effective when an athlete’s fatigue is cumulated over consecutive days, several
sessions a day or through extended competition periods\textsuperscript{14,78}. Therefore, it is possible
that in this study a single netball session, while fatiguing, could not induce a large
enough level of fatigue thus, eliminating the influence of the study’s recovery
modality on performance which may otherwise have been observed if sessions were
cumulated. Indeed, most studies signifying a performance benefit following CWT have shown improvements during endurance tasks, had the current study performed a prolonged exercise similar to that of a netball game thermoregulation may have become compromised thus differences in performance may have become apparent.

Literature on CWT in team sports appears to both support and refute the performance results of the current study. In support of this study’s findings a vast number of studies conducted on AFL, soccer, rugby union and netball players have found no performance differences using similar performance tests (vertical jump and array of agility tests) after CWT recovery interventions\textsuperscript{22,29,32,33,42,43,58}. In contrast, a random control trial on a rugby union team found medium to large effects (d = 0.72) for 300-metre sprint tests following CWT when compared to a control condition preceding a match\textsuperscript{37}. Other team sport studies have explored the effects of blood lactate concentration and creatine kinase effects following CWT. Two studies conducted by Hamlin\textsuperscript{32,33} on development level rugby players and netballers found following a series of repeated sprint tests lower blood lactate levels were recorded after CWT compared to other recovery modalities (active and passive recovery). Unfortunately due to different methodologies and recovery protocols employed in team sport research it is difficult to provide a definitive statement for or against the use of CWT as a recovery modality. Despite this, the use of CWT within team sport continues to gain popularity\textsuperscript{29} thus, future research is needed to determine the true efficacy of this and similar (i.e. CS) recovery modalities.

To the author’s knowledge this is the first study to examine differences in core and skin temperature responses to CWT and CS. No differences in T\textsubscript{core} were observed immediately following exposure to CWT or CS compared to a passive recovery condition; however, differences in the percent decline (post recovery to 20
minutes post recovery) indicates a continued cooling effect of both CWT and CS compared with the control condition and is consistent with previous hydrotherapy research findings\(^{51,52,74}\). For instance, Peiffer et al.\(^{51}\) examined the use of CWI (14°C for 20 minutes) after cycling exercise in heat and observed a delayed \(T_{\text{core}}\) cooling effect, occurring 10 minutes post immersion, compared with passive sitting. The delayed decrease in \(T_{\text{core}}\) following CWI is likely associated with the body’s ability to protect itself against a cold shock through the vasoconstriction of peripheral blood vessels\(^{51,78}\) thus, limiting the contact of blood with the cooler periphery. Similarly, Versey et al.\(^{78}\) observed a delayed cooling response in 11 trained male cyclists who completed a CWT intervention (alternating 1 minute hot; 38°C, 1 minute cold; 15°C for 6, 12 and 18 minutes) following a 75 minute cycling protocol\(^{78}\). The authors postulate that the delayed \(T_{\text{core}}\) changes were associated with an after-drop (hypothermic overshoot) sometimes reported following such recovery interventions\(^{78}\).

Exposure to CWT and CS significantly lowered \(T_{\text{skin}}\) when compared with the passive control condition (Figure 4.3a) and is most likely associated with the large potential stimulus driven through contact with cold water. This finding is particularly important as \(T_{\text{skin}}\) is an integral component of a human’s perception of fatigue and comfort\(^{15,28,62,72}\). Irrespective, an individual’s comfort level improves when the environment allows return of the body’s temperature toward physiological normality\(^{28}\). Indeed in the current study exposure to CWT and CS resulted in a rapid decrease in \(T_{\text{skin}}\) (Figure 4.3a). This change is likely to have accounted for the enhanced post-intervention recovery perceptions (Will/Has statement; Table 3). For instance, Flouris\(^{28}\) reported that humans identify a thermal stimulus as agreeable when it serves to minimise body heat storage, thus feelings of comfort or discomfort...
are dependent on whether the body is in a hypothermic or hyperthermic state. The term “alliesthesia” has recently been devised which expresses the concept of a given temperature stimulus producing pleasure or displeasure depending on a body’s thermal state. Therefore, it is suggested that a positive alliesthesia was observed using CWT and CS as athletes Tskin decreased from a hyperthermic state (39.07°C ± 0.29 °C) thus producing enhanced perceptions when compared with a passive condition.

Hydrostatic pressure is thought to be important in the success of hydrotherapy interventions. This study’s findings, however, do not support this theory as demonstrated by similar performance, cooling, and perceptual measures between CWT and CS. It may be possible that the temperature of the water (similar hot and cold between conditions) was more important than the hydrostatic pressure that accompanied exposure and thus played an integral role in recovery and positive perceptions of these post-exercise recovery strategies. Indeed, Vaile et al. assessed the effectiveness of hydrostatic pressure on recovery using identical hydrotherapy protocols (duration and pressure exerted) of CWI, CWT and HWI and found only CWT and CWI to provide a benefit. From these findings it was suggested that although hydrostatic pressure may contribute to recovery effectiveness, temperature must also play a vital role. Despite CS having minimal hydrostatic pressure the current findings indicate CS can potentially be used as an alternative to traditional water immersion recovery protocols.

Athletic performance is a multidimensional phenomenon, thus it should be acknowledged that adequate recovery should occur on both a physiological and psychological level. Indeed, psychological recovery can play an integral role in optimising recovery as athletes that feel less pain and have a heightened sense of
well-being following recovery interventions are more likely to perform well\textsuperscript{7,55,56,68}. Overall, in the present study CWT and CS were perceived to be more effective modalities than the passive condition. Athletes perceived CWT to be an effective modality before and after the intervention due to positive preconceived perceptions and regular usage of the modality (Table 3). Interestingly CS was originally rated neutral with many netballers unsure of its effectiveness; however, following the intervention CS were rated slightly more effective than CWT. These findings indicate that CS provide a similar, if not greater, psychological benefit compared to CWT after initial exposure thus, the use of CS are a viable alternative to CWT.

The present study provides important information on CS as an alternative recovery modality to commonly used CWT. Nevertheless, while this data does add to the growing body of knowledge in this field, a limitation within the current study design must be acknowledged. In the current study, vertical jump was utilised as a performance measure due to its simplicity and familiarity (routinely used in weekly testing sessions) with the current participants. Vertical jump is an accepted method to measure explosive leg power\textsuperscript{43}; however, even in fatigued states athletes are likely able to produce a “one-off” effort that is close to maximum\textsuperscript{22}. In an attempt to correct for this, the participants performed a repeated vertical jump test. Regardless, the between jump recovery duration (i.e. 15 seconds) may have allowed adequate recovery within each jump session and thus negated any fatigue effect. In addition, despite greater RPE, increased whole body fatigue and increased agility times following the netball specific circuit, vertical jump height increased compared with baseline in all conditions (Figure 4.2). The improved jump results are possibly associated with enhanced neuromuscular activation from the netball specific circuit. Indeed, Cortis et al.\textsuperscript{18} have shown that prior running based exercise can increase
subsequent vertical jump height through enhanced neuromuscular activation\textsuperscript{18}. The young, elite status of the participants may have resulted in them recovering quickly even after a fatiguing exercise bout as supported by Vaile et al\textsuperscript{74}. In the current study the participants were unable to repeat the circuit daily due to training programs, which may have resulted in a positive effect of hydrotherapy if the athletes experienced accumulated fatigue.
CHAPTER SIX: CONCLUSION

The present study has contributed to the limited knowledge base investigating the efficacy of CWT and CS as a viable recovery modality for elite netballers. While no improvements in performances were observed; the current recovery conditions were not harmful to performance and returned performances to pre-exercise levels. Similar skin cooling was observed between CWT and CS, therefore it is suggested that these findings resulted in a greater psychological benefit compared with passive recovery. Together these findings indicate that CWT and CS are viable recovery modalities providing additional recovery methodologies for competitive netballers.
REFERENCES


57. Ryan HJ. The development of a reliable and valid netball intermittent activity test: a thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Sport and Exercise Science at Massey University, Auckland, New Zealand. 2009.
APPENDIX 1: ETHICS APPROVAL LETTERS

Tuesday, 15 March 2011

Dr Jeremiah Peiffer
School of Chiropractic and Sports Science
Murdoch University

Dear Jeremiah,

Project No. 2011/015
Project Title Influence of Contrast Recovery Modalities on Team Sport Performance, Perceptions and Physiological Variables

Thank you for addressing the conditions placed on the above application to the Murdoch University Human Research Ethics Committee. On behalf of the Committee, I am pleased to advise the application now has:

OUTRIGHT APPROVAL

Approval is granted on the understanding that research will be conducted according the standards of the National Statement on Ethical Conduct in Human Research (2007), the Australian Code for the Responsible Conduct of Research (2007) and Murdoch University policies at all times. You must also abide by the Human Research Ethics Committee’s standard conditions of approval (see attached). All reporting forms are available on the Research Ethics web-site.

I wish you every success for your research.

Please quote your ethics project number in all correspondence.

Kind Regards,

[Signature]

Dr. Erich von Dietze
Manager of Research Ethics

cc: Dr Shona Halson
Laura Juliff
Australian Institute of Sport

MINUTE

TO: Ms Laura Juliff

FROM: Ms Helene Rushby

SUBJECT: Approval from AIS Ethics Committee  DATE: 17th February 2011

At the last meeting of the AIS Ethics Committee, held on the 15th of February 2011, the Committee gave consideration to your submission titled ‘Influence of contrast recovery modalities on team sport performance, perceptions and physiological variables’. The Committee saw no ethical reason why your project should not proceed.

The approval number for this project is 20110206.

It is a requirement of the AIS Ethics Committee that the Principal Researcher (you) advise all researchers involved in the study of Ethics Committee approval and any conditions of that approval. You are also required to advise the Ethics Committee immediately (via the Secretary) of:

   - any proposed changes to the research design,
   - any adverse events that may occur,

Researchers are required to submit annual status reports to the secretary of the AIS Ethics Committee until completion of the project. Details of status report requirements are contained in the “Guidelines” for ethics submissions.

This Approval is valid until the 30th March 2012; re-approval will need to be sought should the project continue past this date.

Failure to comply with the above will render ethics approval null and void.

If you have any questions regarding this matter, please don’t hesitate to contact me on (02) 6214 1577.

Sincerely
Helene Rushby
Secretary, AIS EC
## APPENDIX 2: FOOD DIARY

### Day 1:pm  
**Date:** 17 March

<table>
<thead>
<tr>
<th>Meal/Training</th>
<th>Food/Drink</th>
<th>Quantity</th>
<th>Comments e.g. Where you ate</th>
<th>Hunger Rating</th>
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**HUNGER RATING:** (1 = No Appetite – 10 = Extremely Hungry)
A Food and Training Diary can be a useful tool if used correctly. It is a bit like having a video made of your technique because it gives you a chance to look at what you **REALLY** do, rather than what you **THINK** you do. The Food and Training Diary can only be useful if it is a true indication of your typical eating and training habits. Be honest and follow the following guidelines:

- Fill out the diary for 4 consecutive days including one day of the weekend.
- Carry the diary with you at all times and write everything down as it happens. Don’t rely on memory at the end of the day…. a messy diary is a well kept diary.
- Stick to your usual eating habits when you are recording. Don’t eat better than usual to impress us. We are interested in your overall meal plan, not just one particular food. Don’t only eat foods that are easy to record.
- Remember to include all the things that you add to food when eating or cooking (eg. margarine, oil, sugar, dressings).
- Please remember to describe foods in as much detail as possible (eg. white/wholemeal, fat left on/trimmed off, sweetened/unsweetened, full cream/reduced fat).
- List the ingredients and special features of mixed dishes such as pizza, pasta sauce, stir fries, casseroles.
- Record the quantity of foods and fluids as accurately as possible.

You can use any of the following methods:

- **weight** (often written on food packaging)

- **ml** (know the volume of your drink bottle)

- **teaspoons** (heaped or level?)

- **cups** (but not bowls or plates they vary too much in size)

Dimensions (use the grid on the following page of this booklet to estimate)

Only record food that is actually eaten. Don’t record everything you put on your plate if you leave some behind.

The sample on the following page is an example of the detail required
Use this grid to help in determining the amount of food eaten. Take for example a piece of cake 5 x 4 x 3 cm or a piece of beef 10 x 12 x 1.5 cm

1 square = 1 cm

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**Thickness:**

- 1 cm
- \( \frac{1}{2} \) cm
APPENDIX 3: WARM UP

WARM UP

3 x Jog up and back
2 x Skip up and back
Side step up and back
High knee up + Backward run back

Dynamic Stretches
   Leg swings
   Squat and walk etc

Run to centre  2 x 50%
               2 x 80%
               2 x 100%

Side shuffle up and back
Jump on spot   3 x 70%
               3 x 80%
               3 x 90%
APPENDIX 4: ILLUSTRATION OF THE NETBALL CIRCUIT
APPENDIX 6: PERFORMANCE RECOVERY QUESTIONNAIRES

Performance Recovery
Post Interventions Questionnaire
Perceptions of Hydrotherapy as a Recovery Technique

ID: 11

Please place an X on the line to indicate to what extent you agree or disagree with the question below.

Do you believe the post-exercise hydrotherapy technique Passive Recovery will accelerate your recovery in this trial?

• ________________

Performance Recovery
Post Trial Questionnaire
Perceptions of Hydrotherapy as a Recovery Technique

ID: 11

Please place an X on the line to indicate to what extent you agree or disagree with the question below.

Do you believe the post-exercise hydrotherapy technique Passive Recovery has accelerated your recovery in this trial?

• ________________
APPENDIX 7: MENSTRUAL CYCLE QUESTIONNAIRE

MENSTRUAL CYCLE QUESTIONNAIRE

What date did your last menstrual period start? (Place a cross over the date on the calendar below)

When do you anticipate your next menstrual period to start? (Place a circle over the date on the calendar below)

<table>
<thead>
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<th>FEBRUARY 2011</th>
<th>MARCH 2011</th>
<th>APRIL 2011</th>
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<td>SUN MON TUES WED THURS FRI SAT</td>
<td>SUN MON TUES WED THURS FRI SAT</td>
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<td>1 2 3 4 5</td>
<td>1 2</td>
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<td>6 7 8 9 10 11 12</td>
<td>3 4 5 6 7 8 9</td>
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<td>13 14 15 16 17 18 19</td>
<td>10 11 12 13 14 15 16</td>
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<tr>
<td>20 21 22 23 24 25 26</td>
<td>20 21 22 23 24 25 26</td>
<td>17 18 19 20 21 22 23</td>
</tr>
</tbody>
</table>

Do you experience regular periods? YES / NO
Do you use oral contraceptives? YES / NO

<table>
<thead>
<tr>
<th>Date Started</th>
<th>Brand Name</th>
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## APPENDIX 8: RECOVERY SCALES

<table>
<thead>
<tr>
<th>Rating of Perceived Exertion Scale</th>
<th>Thermal Sensations Scale</th>
<th>Whole Body Fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>No exertion at all</td>
<td>0.0 Unbearably Cold</td>
</tr>
<tr>
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<td>Extremely light</td>
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<tr>
<td>8</td>
<td>Very light</td>
<td>1.0 Very Cold</td>
</tr>
<tr>
<td>9</td>
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</tr>
<tr>
<td>10</td>
<td>Somewhat hard</td>
<td>2.0 Cold</td>
</tr>
<tr>
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<tr>
<td>12</td>
<td>Somewhat hard</td>
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</tr>
<tr>
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</tr>
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<td>16</td>
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<td>5.0 Warm</td>
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</tr>
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<td>19</td>
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</tr>
<tr>
<td>20</td>
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<td>7.0 Very Hot</td>
</tr>
<tr>
<td></td>
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<td>7.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.0 Unbearably Hot</td>
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