ABSTRACT

IMPLICATIONS OF COLD WATER IMMERSSION ON PERFORMANCE RECOVERY IN ATHLETES WITH EXERCISE INDUCED HYPERTHERMIA

Exercise induced hyperthermia (EIH) has been related to performance fatigue in many athletic settings. Fortunately, if treated quickly heat related stress can be reduced and even eliminated by lowering core temperature (CT). Cold water immersion (CWI) has been labeled as the gold standard method to reduce CT. However, little research exists evaluating the effects of a post exercise CWI on exercise performance in athletes with EIH. The purpose of this study was to examine if a post exercise CWI intervention supported exercise recovery in athletes with EIH. It was hypothesized that a post exercise CWI intervention would support exercise performance and aid physiological recovery 24 hr between exercise bouts. Four male volleyball athletes performed repeated maximal exercise tests and were randomly selected for a Passive or CWI intervention. Performance was measured using the Yo-Yo intermittent recovery test level 1 (IRTL1) and the Sargent Jump Test (SJT) and physiological recovery was measured using heart rate (HR), blood lactate (BL), and CT. Repeated measures were used for both interventions. No significant differences were found between the interventions and exercise performance; SJT (p=0.19) & IRTL1 (p=0.13) or physiological recovery; HR (p=0.66), BL (p=0.65), & CT (p=0.63). Univariate ANOVA’s were used to determine differences in the dependent variables.

Eric Bryce Middleton
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IMPLICATIONS OF COLD WATER IMMERSION ON PERFORMANCE RECOVERY IN ATHLETES WITH EXERCISE INDUCED HYPERTHERMIA

by

Eric Bryce Middleton

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APPROVED

For the Department of Kinesiology:

We, the undersigned, certify that the thesis of the following student meets the required standards of scholarship, format, and style of the university and the student’s graduate degree program for the awarding of the master’s degree.

________________________________________
Eric Bryce Middleton
Thesis Author

________________________________________
Tim Anderson
Kinesiology

________________________________________
Michael Coles
Kinesiology

________________________________________
Dawn Lewis
Kinesiology

For the University Graduate Committee:

________________________________________
Dean, Division of Graduate Studies
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In addition, I want thank Dr. David Kinnunen who encouraged me to strive for nothing less than excellence "Do Good Work".

"Do not ask what the world needs. Ask instead what makes you come alive.

   What the world needs is those who have come alive."

-Howard Thurman
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CHAPTER 1: INTRODUCTION

Overview of the Problem

Athletes who regularly perform prolong or physically demanding exercise in the heat often reach core body temperatures which exceed or are equivalent to 38 ± 0.5°C (Bouchama & Knochel, 2002; Limire, 2008; McDermott et al., 2009; Nybo, 2008). Elevations in core temperature due to exercise or exercise induced hyperthermia (EIH) is commonly observed, however research suggests that the physiological effects of EIH can handicap sports performance and perpetuate heat illnesses (Bouchama & Knochel, 2002; McDermott et al., 2009).

Thermoregulation such as perspiration and vasodilatation is usually adequate in dissipating heat, but excessive environmental and metabolic thermal stress can overload these cooling systems. Nybo and Limire reported that core temperatures at or above 38°C may cause significant physical discomfort and impede sports performance during prolonged and/or repeated exercise. If core temperatures continue to rise past 38.5°C, EIH can evolve into a severe heat illness (Bouchama & Knochel, 2002; Brooks, Fahey, & Baldwin, 2005; Mazerolle et al., 2010). Studies have shown that when core temperatures reach or exceed 40°C, exertional heat stroke (EHS) may develop which can lead to organ dysfunction and potential death (Bouchama & Knochel, 2002; Mazerolle et al., 2010). Preventive measures are usually taken in athletic settings to diminish these effects, however EIH can be devastating to sports performance and health if gone undetected. Without proper cooling EIH can have a negative accumulative effect on sports performance as well as increase the risk of developing heat illnesses (Bergeron, 2009; Bouchama & Knochel, 2002; Nybo & Nielsen, 2001). Since the implications of EIH can be
profound, proper management of thermal stress during exercise is essential for exercise performance, recovery, and safety.

Although various options exist for treating heat illness, ample research has concluded that thermal convection by cold water immersion (CWI) is the most effective method in reducing core temperatures and is currently used by the American College of Sports Medicine (ACSM) and National Athletic Trainers' Association (NATA) to treat EHS (Bouchama & Knochel, 2002; Clements et al., 2002; Fröhlich et al., 2014; "Glossary of Terms for Thermal Physiology: Second Edition," 1987; McDermott et al., 2009; Proulx, Ducharme, & Kenny, 2006). Though CWI may reduce the risk of heat illness, there is conflicting research exploring the effects of post exercise CWI interventions on exercise recovery and/or performance. Ascensão, Leite, Rebelo, Magalhães, and Magalhães (2011) and Brophy-Williams, Landers, and Wallman (2011) both found that immediate post exercise CWI interventions have the potential to alleviate muscle damage and discomfort resulting in faster recovery and better performance. However, meta analysis's on the topic are less conclusive and suggest that although there is a positive correlation between CWI interventions and recovery in some literature, other studies have found that there is little to no affect on recovery of muscular strength and performance (Leeder, Gissane, van Someren, Gregson, & Howatson, 2012; Pournot et al., 2011; White & Wells, 2013). Due to these disagreements it is difficult to determine the efficacy of post exercise CWI interventions as an effective exercise recovery modality. Thus it may be beneficial to study the effects of post exercise CWI on exercise recovery and/or performance in athletes with EIH. By incorporating EIH, research may be able to more clearly define the role of post exercise CWI as not only a treatment option for heat illnesses, but also potentially a recovery method for exercise performance. Existing research
suggests that post exercise CWI may be extremely valuable to the athletic community by not only reducing the risk of serious heat illnesses but by also potentially providing additional exercise recovery between repeated high intensity exercise bouts (Leeder et al., 2012; White & Wells, 2013). However, more research is needed to verify these conclusions.

**Purpose Statement**

The purpose of this research was to evaluate if a CWI intervention aids performance recovery ≈ 24 hr after repeated maximal exercise in athletes with EIH. Secondly, this study evaluated the effects of a CWI intervention on blood lactate (BL) clearance, heart rate (HR) recovery and core temperature (CT).

**Research Questions**

1. Will a post exercise CWI intervention improve performance recovery ≈ 24 hr after repeated maximal exercise in athletes with EIH?

2. Will there be an association between a CWI intervention and the rate of decline in physiological recovery variables; HR, BL, and CT?

**Hypotheses**

1. The application of a CWI intervention will significantly enhance performance recovery of maximal vertical jump (SJT) and exhaustive intermittent sprints (IRTL1) ≈ 24 hr after repeated maximal exercise in athletes with EIH compared to Passive Recovery.

2. There will be a greater magnitude of change in the physiological recovery variables; heart rate (HR), blood lactate (BL), and core temperature (CT) after a CWI intervention compared to Passive Recovery.
Significance

Athletes who participate in tournament sports are often subject to multiple rounds of sub-maximal to maximal exercise with relatively short amounts of rest (Bergeron, 2009). These kinds of events are common in the athletic community, and may result in an elevation in core temperature known as EIH (Bergeron, 2009). Although EIH is not uncommon, studies suggest the persistent EIH can inhibit athletic performance and slow recovery (Bouchama & Knochel, 2002; Nybo, 2008). CWI has been regularly used to treat hyperthermia and heat illnesses (McDermott, 2009), however CWI lacks scientific evidence supporting its efficacy as exercise recovery modality. Many studies have evaluated the effects of a post exercise CWI intervention on exercise recovery, but many of the results are contradictory. Thus, the results of this study may help clarify the efficacy of post exercise CWI as an exercise recovery option in athletes with EIH. In addition, it may help athletes, coaches, and fitness professionals who exercise regularly in the heat develop more effective recovery strategies.

Delimitations

1. Participants were males from a collegiate club volleyball team.
2. Performance recovery variables were limited to maximal vertical jump (SJT), and distance traveled (IRTL1).
3. Pre and post intervention exercise testing started at similar times of the day within a 24 hr span.
4. All food and drink was restricted 1 hr prior to exercise trials.

Limitations

Study results are generalized to:

1. Male collegiate club volleyball athletes.
2. Post exercise CWI protocol; submersion to the clavicle at ≈14°C for 15 min.
3. Recovery of maximal vertical jump (SJT), and distance traveled (IRTL1).
4. A recovery period of 24 hr.

Assumptions
1. Participants abstained from all exercise, anti-inflammatory drugs (NSAIDS), pain medications, alcohol, and stimulants 24 hr prior to and during the duration of the study.
2. Participants maintained similar dietary and sleeping habits during the duration of the study.
3. Participants gave maximal effort during all exercise testing trails.
4. Participants had similar body composition profiles.
5. Participants were similarly heat acclimated.
6. Participants were similarly hydrated during the course of the exercise testing.

Definition of Terms
Cold Water Immersion - Cooling of the body by conduction, commonly used to alleviate hyperthermia, exercise induced hyperthermia, and heat illnesses (Bouchama & Knochel, 2002; McDermott et al., 2009).

Exercise Induced Hyperthermia - A state of hyperthermia (38 ± 0.5°C) induced by metabolic thermal stress (e.g. physical exertion) commonly associated with prolonged environmental heat exposure which overwhelms natural thermoregulation ("Glossary of Terms for Thermal Physiology: Second Edition," 1987).

Exertional Heat Stroke - Serious medical condition when core temperatures exceed 40°C which can lead to serious injury and death. Predominately occurs
when athletes are required to perform high intensity exercise in hot or humid environments (Mazerolle et al., 2010).

**Heat Illness** - Potentially fatal physical illness that develops due to an overload of thermal stress. Some heat illnesses include heat exhaustion, heat stroke, and exertional heat stroke (Bouchama & Knochel, 2002).

**Hyperthermia** - Elevation of core temperature greater than the normal hypothalamic set point ($37 \pm 0.5^\circ C$) caused by impairments in natural thermoregulation by drugs, disease or prolong exposure to hot environmental and/or metabolic thermal stresses (Bouchama & Knochel, 2002).

**Hypothermia** - Decreases in core temperature (<$35^\circ C$) lower than the normal hypothalamic set point ($37 \pm 0.5^\circ C$) caused by excessive heat loss or prolong exposure to cold environmental thermal stresses ("Glossary of Terms for Thermal Physiology: Second Edition," 1987).

**Normothermia** - Also known as cenothermy, when core temperatures are within $\pm 1 \text{ SD}$ of normal resting levels ($37 \pm 0.5^\circ C$) (Bouchama & Knochel, 2002; "Glossary of Terms for Thermal Physiology: Second Edition," 1987).

**Thermal Conduction** - The process of heat transfer from one object or material to another which are in touching ("Glossary of Terms for Thermal Physiology: Second Edition," 1987).

**Thermoregulation** - Process of regulating internal temperatures by metabolic heat and controlling the rate of heat loss (e.g. sweating and vasodilatation) ("Glossary of Terms for Thermal Physiology: Second Edition," 1987).

**Thermal Stress** - Physiological strain associated with an exposure to a hot or cold environment(s) which can alter normothermia ("Glossary of Terms for Thermal Physiology: Second Edition," 1987).
CHAPTER 2: REVIEW OF LITERATURE

Exercise Induced Hyperthermia & Fatigue

A recent meta-analysis by Nybo, reported that the major consequences of EIH on performance were related to central nervous system (CNS) control, cardiac efficiency, and muscle function. A number of these studies concluded that EIH resulting from prolonged high intensity exercise and elevated environmental temperatures can trigger a physiological heat-stress response, which shunts blood away from ventral organs to peripheral tissues via vasodilatation (Bouchama & Knochel, 2002; Nybo, 2008). If left untreated, this response may promote central hypotension which can decrease cardiac output and VO₂ max diminishing aerobic performance (Nybo, 2008). Although other literature has shown that in passive states this redistribution of blood removes excess heat from the system, during high intensity activity it may further handicap performance and/or the safety of the athlete (Bouchama & Knochel, 2002; Nybo, 2008). Likewise, reductions in central blood have also been related to cerebral ischemia and neuromuscular dysfunction (Bouchama & Knochel, 2002; Nybo, 2008). One study comparing the effects of exhaustive exercise in different temperature settings (40°C versus 18°C) found that participants exercising at 40°C reached core temperatures of 40 ± 0.1°C and had significantly greater decreases in motor performance and central activation (Nybo & Nielsen, 2001). The study also found that despite the cooler environment, participants exercising at 18°C also had significantly higher core temperatures of 38 ± 0.1°C. Suggesting that even in cooler environments, prolonged exercise can still significantly elevate core temperatures and potentially lead to decreases in athletic performance. Thus, cognitive, cardiovascular, and neuromuscular performance may be drastically handicapped by EIH even in
environments in which ambient temperatures are cooler (Bouchama & Knochel, 2002; Nybo, 2008; Nybo & Nielsen, 2001; Ross et al., 2012).

Apart from cardiac and cognitive deficits, the redistribution of central blood due to high intensity exercise in the heat may promote the build-up of extramuskular and intramuskular fluid (edema) within and near muscle tissues (Bouchama & Knochel, 2002; Leeder et al., 2012; White & Wells, 2013). Studies suggest that the direct mechanical stress exerted on muscle tissues by edema may alter muscle excitation-contraction coupling and increase delayed onset muscle soreness (DOMS) (Leeder et al., 2012; White & Wells, 2013; Yanagisawa, Niitsu, Takahashi, Goto, & Itai, 2003). While other literature found that edema may compress capillary circulation to skeletal muscles and interfere with oxygen delivery and metabolite clearance (Bouchama & Knochel, 2002; Leeder et al., 2012; Nybo, 2008; White & Wells, 2013; Yanagisawa et al., 2003). It is understood that if muscle ischemia becomes severe, tissue hypoxia (lack of adequate oxygen) may occur which can lead to secondary muscle damage (non-exercise related muscle damage) and provoke an inflammatory reaction (Bouchama & Knochel, 2002; Leeder et al., 2012; White & Wells, 2013; Yanagisawa et al., 2003). Research shows that high intensity exercise in the heat perpetuates tissue hypoxia and can compromising cellular structures leading to apoptosis (cell death) (Bouchama & Knochel, 2002; Leeder et al., 2012; Nybo, 2008; White & Wells, 2013). Furthermore, these studies suggest that muscle ischemia may promote the accumulation of noxious metabolites such as free radicals (reactive oxygen, and reactive nitrogen species) within active muscle tissues which often disrupt muscle function, osmotic gradients and lead to further inflammation (Bouchama & Knochel, 2002; White & Wells, 2013). Although inflammatory responses are usually beneficial in mediating stress, research has
shown that inflammatory endothelial and cytokine factors such as nitric oxide may inhibit proper thermoregulation increasing the risk of heat illness (Bouchama & Knochel, 2002). Altogether it has been well documented that EIH may reduce capillary blood flow and promote the accretion of toxic metabolites further leading to reductions in muscle metabolism, secondary muscle damage, and inflammation (Allen, Lamb, & Westerblad, 2008; Bouchama & Knochel, 2002; Brooks et al., 2005; White & Wells, 2013). Thus one can see that EIH if not adequately managed can have severe consequences on health and exercise performance.

**Cold Water Immersion**

Though various options exist for treating hyperthermia, cooling by conduction or CWI has been found to be an safe effective tool in quickly lowering core body temperatures in individuals with severe hyperthermia (Bouchama & Knochel, 2002; Clements et al., 2002; Fröhlich et al., 2014; McDermott et al., 2009; Proulx et al., 2006). Furthermore, CWI is recommended by the American College of Sports Medicine (ACSM) and the National Athletic Trainers' Association (NATA) as a treatment option for EHS (McDermott et al., 2009). McDermott et al. concluded that although no standard CWI protocol has been established, studies suggests that CWI interventions of 14°C and lower were ideal for reducing core body temperatures in a timely manner. It has also been reported that CWI at 14°C can lower core temperatures of ≈40°C back to resting levels of ≈37.5°C within 17.3 ± 4.5 min (Proulx et al., 2006). Proulx et al. also mentioned that no significant differences were found between CWI interventions of 8°C and 14°C and their subsequent cooling rates. However, CWI interventions using extremely low water temperatures (≤ 8°C) have been shown to decrease core body temperatures to ≈ 35°C increasing the risk of cold stress and hypothermia (Proulx
et al., 2006). Hence, it may be implied that using a CWI protocol of 14°C is more practical for treating EIH, and is less likely to induce hypothermic stress (Peiffer, Abbiss, Watson, Nosaka, & Laursen, 2009, 2010; Proulx et al., 2006). Therefore, the use of a CWI intervention at 14°C may be one of the most effective and safe methods to lower core body temperatures in individuals with EIH.

**Cold Water Immersion & Exercise Induced Hyperthermia**

Although CWI has been found to be an effective tool for treating hyperthermia, there is much debate whether it is beneficial as a performance recovery option. Some studies have suggested that post exercise CWI interventions have ergogenic effects on exercise recovery, and several have reported that CWI interventions after high intensity exercise may cause vascular vasoconstriction and reduce edema (Ascensão et al., 2011; Brophy-Williams et al., 2011; Leeder et al., 2012; Vaile et al., 2011; White & Wells, 2013). Thus, potentially improving recovery between subsequent high intensity exercise bouts by limiting secondary muscle damage and DOMS (Ascensão et al., 2011; Brophy-Williams et al., 2011; Leeder et al., 2012; Pournot et al., 2011; White & Wells, 2013). Leeder et al. and White and Wells also discussed the potential benefit of hydrostatic pressure applied to the body due to whole body CWI. Both authors suggested that the squeezing effect from the water immersion may increase venous return as well as reduce peripheral inflammation. Other studies found that post exercise CWI may improve cardiac function (increased preload/stroke volume) and arterial circulation (Buchheit, Peiffer, Abbiss, & Laursen, 2009; Vaile et al., 2011; White & Wells, 2013). For example, Buchheit et al. and White and Wells concluded that post exercise CWI interventions may promote faster recovery of heart rate (HR) and venous return after high intensity training. While Yanagisawa
et al. found evidence that post exercise CWI may decrease the accumulation of metabolites (e.g., lactate) due to increased blood profusion to active muscle tissues.

Post exercise CWI has further been utilized as a recovery method for motor performance between subsequent high intensity exercise bouts (Ascensão et al., 2011; Brophy-Williams et al., 2011; Fröhlich et al., 2014; White & Wells, 2013). Despite clear documentation that muscle cooling is counterintuitive to muscle excitation-contraction coupling (Brooks et al., 2005), there is literature suggesting that post exercise CWI may improve muscular strength and power (Ascensão et al., 2011; Pournot et al., 2011; White & Wells, 2013). For example, these studies show that post exercise CWI interventions may increase maximal isometric voluntary contraction (MIVC) and maximal vertical counter movement jump (CMJ) between HIIT sessions (Ascensão et al., 2011; Brophy-Williams et al., 2011; Pournot et al., 2011). Thus, post exercise CWI may have the potential to decrease the recovery time needed to maintain muscular power and strength between consecutive exercise sessions. In the same way, post exercise CWI interventions may also be a successful recovery method for endurance athletes. Studies suggest that post exercise CWI interventions on long distance runners may improve performance times between exhaustive running bouts (Clements et al., 2002; Dunne, Crampton, & Egana, 2013); implying that post exercise CWI may be an effective tool and recovery method for distance runners which does not appear to impair motor function.

Conversely, other literature suggests that the application of post exercise CWI has little to no effect on subsequent exercise recovery and/or performance (Gonzalez et al., 2014; Leeder et al., 2012; Rupp et al., 2011; Stanley, Buchheit, & Peake, 2012). Instead, these studies reported that the treatment did not produce
significant performance differences from control groups. Gonzalez et al. found that post exercise CWI did not provide additional strength and/or endurance recovery in forty participants during consecutive resistance training. The study concluded that post exercise CWI had no significant effect on reducing recovery time or limiting exercise induced muscle damage (EIMD). Furthermore, Rupp et al. found similar results and noted that post exercise CWI interventions did not provide substantially better exercise recovery compared to the control groups in 22 trained soccer athletes during successive HIIT. Likewise, a meta-analysis by Leeder et al. concluded that though post exercise CWI interventions may alleviate DOMS, evidence suggests that it does not provide any enhancements in strength recovery. Furthermore, it is also been proposed that post exercise CWI interventions may reduce natural inflammation which occurs in muscle tissues after resistance and/or high intensity exercise. Fröhlich et al. (2014) suggested that without this natural inflammatory process, hormones which aid in muscle growth and repair such as testosterone, growth hormone, and insulin-like growth factor-1 may be inhibited. Thus, the long term application of post exercise CWI may be detrimental to strength and conditioning programs and athlete development.

It must be noted that although post exercise CWI has been commonly used, no standard protocols or procedures have been established regarding its application in performance settings. Therefore, it is difficult to fully understand the physiological implications of post exercise CWI on exercise and/or performance, however systemic reviews and meta-analysis's evaluating the efficacy of post exercise CWI as a recovery option agree that the intervention may enhance performance recovery (Leeder et al., 2012; McDermott et al., 2009; White & Wells, 2013). It is clear that further research is needed to help solidify the practicality of this recovery method on exercise recovery and/or performance.
Although there is a lack of agreement between studies on exercise performance and post exercise CWI interventions, the application of post exercise CWI as a recovery method in the presence of EIH may be more insightful. White and Wells reported that the larger the temperature gradient between the cooling treatment (CWI), and one's core temperature (hyperthermia), the greater the physiological change and subsequent recovery. Thus EIH may enhance the physiological effects of post exercise CWI on exercise recovery and/or performance. Though the results of the literature are inconclusive, evidence suggests that post exercise CWI in normothermic conditions may have the potential to improve exercise recovery during subsequent high intensity exercise bouts (Ascensão et al., 2011; Brophy-Williams et al., 2011; Buchheit et al., 2009; Leeder et al., 2012; Pournot et al., 2011; White & Wells, 2013; Yanagisawa et al., 2003). In addition, it has also been well documented that post exercise CWI is useful in reducing core temperatures in a variety of situations, especially in individuals with EIH (Bouchama & Knochel, 2002; Clements et al., 2002; McDermott et al., 2009; Peiffer et al., 2009; Proulx et al., 2006; White & Wells, 2013). Therefore it may be implied that the effects of post exercise CWI on exercise recovery and/or performance in athletes with EIH may drastically improve ability to recovery from otherwise compromising physiological changes. Moreover, to the authors knowledge there has been little research completed comparing the effects post exercise CWI on exercise recovery and/or performance in individuals with EIH. Of these few studies two of them found that post exercise CWI did not effectively improve recovery of isometric strength and/or power after prolonged cycling bouts in the heat (Peiffer et al., 2009, 2010) However, these studies only evaluated the immediate impact of post exercise CWI on exercise recovery, and did not explore the potential long term effects of the treatment.
Subsequently, both authors confessed that excess cooling may have interfered with muscle function and acute strength and power measurements. Thus, extending the time between treatments and test variables may allow muscle temperatures to again reach normal levels improving strength and power measurements. In contrast, other studies noted that CWI interventions may improve the recovery time of heart rate (HR) and acute muscular strength following exhaustive intermittent exercise in the heat (Buchheit et al., 2009; Pointon, Duffield, Cannon, & Marino, 2012). Supporting the theory that post exercise CWI may improve exercise recovery and/or performance in hyperthermic conditions.

Conclusion
Due to the lack of research and inconsistencies between study methodologies it is irrelevant to form a conclusion regarding the efficacy of post exercise CWI interventions on exercise recovery and/or performance in the heat. To better understand the implications of post exercise CWI on subsequent exercise recovery and/or performance in individuals with EIH additional research is needed.
CHAPTER 3: METHODS

Research Design

This study used a randomized repeated measures design to measure the dependent variables. Testing was separated into 2 rounds; round 1 (days 2 & 3) and round 2 (days 4 & 5). Day 1 was used to brief the participants on the experimental procedures and to familiarize them with the exercise protocols. During the start of the first round (day 2) participants met in the human performance lab (HPL) and rested 1 hr before the start of the exercise trials. Each participant then performed three repeated maximal Sargent Jump Tests (SJT), and three repeated maximal intermittent recovery tests level 1 (IRTL1). Once the participants completed the exercise trials, they were randomly selected for one of two 15 min recovery interventions; CWI or passive recovery. On day 3 participants returned to the HPL and repeated the same testing procedures as day 2, however no recovery intervention was administered. After the final exercise test was completed the participants were released but asked to return at a scheduled time and date to complete the second round of testing (days 4 & 5). During round 2, the participants returned to the HPL and repeated the same testing procedures as round 1, however the opposite recovery intervention was administered. At the completion of round 2 the participants were released from the study. Pre and post intervention measurements for SJT and IRTL1 were recorded for both recovery methods and were used to assess performance recovery. In addition, physiological recovery variables of heart rate (HR), blood lactate (BL), and core temperature (CT) were recorded on days 2 and 4, and were used to assess physiological recovery. Dependent variables in this study were the SJT, IRTL1, HR, BL, and
CT, and the independent variable in this study was the two level recovery intervention (CWI & passive recovery).

**Participants**

Four healthy male collegiate volleyball athletes ages 18-20, height ($M=71.75\text{in}, SD=5.19$), weight ($M=193.75\text{lbs}, SD=30.47$), and body fat ($M=18.33\%, SD=6.25$) volunteered for this study. The participants were active members of a club volleyball team and participated in the team's regular practices and strength and conditioning workouts. Two of the participants had over 5 years of experience playing competitive volleyball, one had between 3-4 years experience and one had between 1-2 years experience. Two participants were of Latin/South American descent, one of European (White), and one of mixed origin (White/Mexican).

**Instruments**

**Informed Consent Form (ICF)**

The informed consent form (see Appendix A) was administered and signed by all participants who volunteered to participate in the study. This form outlined the requirements, methods, and risks of research involvement and established the protection and rights of each participant in accordance with The Committee on the Protection of Human Subjects at the California State University, Fresno. Participants who failed to sign this form were dropped from research participation.

**Participant Medical & Demographics Questionnaire (PMDQ)**

The participant medical and demographics questionnaire (see Appendix B) evaluated demographical items such as ethnicity, age, gender, activity level,
height, weight, medical history, and exercise readiness. In addition this questionnaire was used to identify specific variables needed for participant recruitment.

**Tanita Body Composition Analyzer**

The Tanita Body Composition Analyzer (Tanita Corp., Arlington Heights, Illinois) was used to measure body composition for demographical purposes. Using bio-electrical impedance analysis, measurements of fat free mass, fat mass, and percent body fat were recorded for each participant.

**Health & Fitness Facility Pre-participation Screening Questionnaire (HFFPSQ)**

The Health & Fitness Facility Pre-participation Screening Questionnaire (Balady et al., 1998) was used to assess contraindications for exercise and participants ability to safely complete all required maximal exercise tests and measurements before participation (see Appendix C). If any participants marked "true" to one or more of the questions/statements in the History, Symptoms, and Other health issues sections or marked "true" to two or more of the questions/statements in the Cardiovascular risk factors section, then they were required to provide documented clearance from their primary care provider to continue participation. Participants who failed to meet or adhere to these guidelines were dropped from research participation.

**Perception II Indoor Climate Sensor**

The Perception II was a research grade indoor climate sensor (Davis Instruments, Hayward, California) and was used to monitor the relative humidity and temperature of the indoor gym climate during all exercise testing trails.
Polar FT7 Heart Rate Monitor

The Polar FT7 was a waterproof heart rate monitor (Polar, Kempele, Finland) and was used to measure heart rates during rest, exercise, and recovery. During the heart rate measurements, the Polar FT7 heart rate electrode was fastened directly above the Xiphoid process between the thorax and abdomen using an elastic band and a wireless watch receiver was worn on the left wrist. Before application, conducting gel was applied to the base of the electrode to improve electrical conductivity and improve heart rate measurements.

Thermalert TH-8 Digital Thermometer

The Thermalert TH-8 (Physitemp Instruments Inc., Clifton, New Jersey) was a research grade digital thermometer and was selected to measure water temperatures during the CWI recovery. The TH-8 instrument accuracy ranges from 0.1°C (+0.2 degrees)±1 digit at 25°C ambient and has a repeatability of ±0.1°C.

Ret-1 Thermocouple

The Ret-1 thermocouple (Physitemp Instruments Inc., Clifton, New Jersey) was a 5 ft reusable temperature probe and was used in conjunction with TH-8 to measure all CWI intervention temperatures. During the CWI intervention the Ret-1 thermocouple was inserted 1.5 ft into a 1 in by 3 ft ventilated PVC pipe and was fastened to the inner wall of the hydrotherapy tank. The PVC pipe was implemented to insulate the Ret-thermocouple from the participant and the walls of the aluminum tank. After the CWI intervention was administered the Ret-1 thermocouple was disinfected using a 90% isopropyl or 70% ethyl alcohol swab and hung in a properly ventilated room to air dry (HICPAC, 2008).
DataTherm II

The DataTherm II & Data Therm II Disposable Thermometer (Geratherm Medical AG, Geschwenda, Germany) was used to measure core temperatures during rest, exercise, and recovery. According to the manufacturers, the device has a temperature measurement range of 17-45°C and is accurate ±0.1°C between readings of 34-42°C. In addition, ideal operating conditions were suggested to be within 26-60°C and 10-83% humidity.

After being briefed on proper application and disinfection techniques according to manufacturers recommendations and the 2008 Centers for Disease Control (CDC) guidelines, each participant rectally self administered the DataTherm II disposable thermometer (HICPAC, 2008). Participants entered a designated private bathroom wearing non-latex gloves and protective eyewear and were instructed to use a 90% isopropyl or 70% ethyl alcohol swab to sanitize the head and shaft of the thermometer (HICPAC, 2008). Participants then used a petroleum jelly lubricant and inserted the thermometer 4 cm into the rectum. After insertion, the participants disposed of the protective gloves and alcohol swabs in a biohazard container and exited the bathroom. Core temperature measurements were read and recorded by connecting the thermometer cord to the Data Therm II digital display device. Once all core temperature measurements were recorded, participants again entered the private bathroom wearing non-latex gloves and protective eyewear and removed the thermometer. The used thermometer, and protective gloves were then disposed of in a biohazard container. The thermometer insertion procedures outlined above were repeated for every thermometer application. Furthermore, participants were given their own individual thermometer. Thermometers were not used on multiple subjects.
The method of measuring core temperatures rectally was selected due to its accuracy and reliability during EIH. Research suggests that other core temperature methods such as aural/tympanic, axillary, forehead, oral and temporal artery measurements do not accurately represent core temperatures in hyperthermic exercising humans (Huggins, Glaviano, Negishi, Casa, & Hertel, 2012). Other research noted that tympanic measurements significantly underestimated core temperatures during exercise (Easton, Fudge, & Pitsiladis, 2007). Furthermore, the American College of Sports Medicine (ACSM) and National Athletic Trainers’ Association (NATA) both recommend rectal thermometers as a superior means to measure core temperatures (Huggins et al., 2012). Given the nature of this study and the available data, rectal thermometers were selected as an appropriate means to measure core temperature.

**Ethyl & Isopropyl Alcohols**

Ethyl and Isopropyl alcohols at concentrations of 60-91% were chosen as chemical disinfectant for blood lactate measurements and rectal thermometer preparation to meet the Centers for Disease Control (CDC), 2008 Guidelines for Disinfection and Sterilization in Healthcare Facilities (see Appendix D). The CDC stated that ethyl and isopropyl alcohols at concentrations of 70-90% were potent bactericidal, fungicidal, virucidal, and tuberculocidal agents (HICPAC, 2008, pp. 38-39). For example studies suggest that ethyl alcohols are effective in inactivating all of the lipophilic viruses including herpes, vaccinia, and influenza as well as many hydrophilic viruses including adenovirus, enterovirus, rhinovirus, and rotaviruses (HICPAC, 2008). In addition, the CDC also stated that that ethyl alcohols and isopropyl alcohols were also agents which inactivated hepatitis B virus (HBV), human immunodeficiency virus (HIV), rotavirus, echovirus, and
astrovirus given appropriate exposure times (HICPAC, 2008). Furthermore, ethyl alcohols were also labeled as strong bacterialcidal disinfectants. Tests revealed that at concentrations of 95%, ethyl alcohol killed tubercle bacilli within 15 s of its exposure and concentrations of 70% ethyl alcohol killed Cryptococcus neoformans, Blastomyces dermatitidis, Coccidioides immitis, Psuedomonas aeruginosa, Serratia marcescens, Salmonella typhosa, Streptococcus pyogenes, and Histoplasma capsulatum. However, other studies found that culture phases Cryptococcus neoformans, Blastomyces dermatitidis, Coccidioides immitis, and Histoplasma capsulatum were more resistant to ethyl alcohols and required up to 20 min of exposure time to be fully destroyed unlike the tissue phases which took <1 min (HICPAC, 2008). Alcohols were also effective at destroying dehydrogenases of Escherichia coli and ethyl alcohols effective at increasing the lag phase of Enterobactor aerogenes (HICPAC, 2008). Furthermore, the CDC also stated that isopropyl alcohols at concentrations of 20% were effective at killing cysts of Acanthamoeba culberstoni (HICPAC, 2008). In addition it was discovered that isopropyl alcohols were more bacterialcidal against Staphylococcus aureus and Escherichia coli than ethyl alcohols. The CDC further stated that the optimum bacterialcidal concentrations of alcohols were between 60-90% (HICPAC, 2008). Overall, the CDC stated that ethyl alcohols were potent against a multitude of microorganism but required up to 1 hr of exposure time to be an effective bacterialcidal agent. However, the CDC did state that alcohols lack sporicidal properties and should not be used for items which present a high risk for infection (e.g. instruments which come in contact with sterile tissues) but have been effectively used to disinfect oral and rectal thermometers (Frobisher, Sommermeyer, & Blackwell, 1953; Sommermeyer & Frobisher, 1953).
To maximize participant safety, alcohols were used as a preparatory measure to disinfect the participants’ skin before lactate measurements and disinfect thermometers before insertion. To eliminate potential cross contamination, equipment which was soiled during either blood lactate and/or CT measurements were discarded and not reused.

**Yo-Yo Intermittent Recovery Level 1 Test (IRT1)**

The IRT1 was selected due to its accuracy and reproducibility in homogeneous athletic populations in measuring exhaustive intermittent exercise (Krustrup et al., 2003) (see Appendix E). This test was administered to measure aerobic and anaerobic performance recovery in participants pre and post intervention. Test and re-test results in 13 male soccer athletes demonstrated that IRTL1 had a high reproducibility with a coefficient of variance of 4.9%. Significant correlations were also found comparing the IRTL1 to an exhaustive incremental treadmill test. Results of time to fatigue between the two tests revealed strong similarities ($r = 0.79, P < 0.05$). Furthermore using individual relationships between maximal oxygen uptake and heart rate during the exhaustive incremental treadmill test, oxygen uptake for the IRTL1 test was also significantly correlated ($r = 0.71, P < 0.05$). Likewise, a mutual correlation was also found between time to fatigue and maximal oxygen uptake during the IRTL1 ($r = 0.86, P < 0.05$).

The IRTL1 consisted of two 20 m sprints (1 lap) followed by a 10 second rest regulated by audible beeps. These beeps initiated the start of each 20 m sprint as well as indicated times of rest. At the sound of the first beep, the participants sprinted down a measured 20 m course clearly marked by cones on the ground. If the participant successfully completed the 20 m sprint before or at the sound of the
second beep, they then sprinted back to the starting line before or at the sound the third beep. The third beep also indicated the start of the 10 second rest before the next lap began. If the participants consecutively failed twice to successfully complete the length of the 20 m sprint course before the sound of the second or third beeps, the test was terminated and distance traveled was recorded. In addition, an active recovery path was also marked by 2 cones which were centered 5 m behind the start and finish lines of the sprint course. At the finish of each sprint, the participants decelerated and circled back around the active rest cones returning back to the sprint line. In total 6 cones were used, 4 which were placed 2 m × 20 m creating the length of the sprint course (2 m=start/finish lines, 20 m=sprint path) and 2 which marked the active recovery path. As the participants completed each lap, the audible beeps progressed and sounded more frequently giving the participants less time to finish each sprint. The objective of the test was to complete as many laps and/or travel as much distance as possible before exhaustion.

Team Beep Test Software (TBTS)

The team beep test software (Bitworks, Cheltenham, United Kingdom) was used to administer the IRTL1 beep test protocol. The software was an automated system which effectively regulated the progression of the IRTL1. In addition this program provided a means of tracking participant performance data during the exercise trials.

Sargent Jump Test (SJT)

The SJT was selected due to is accuracy and reproducibility in homogeneous athletic populations in measuring explosive strength and power (Fonseca, & Dantas, 2012). The validity of the test was compared to a jump
platform system using photoelectric receptors to accurately gauge flight time. Jump height was calculated by using the measured flight time in the following equation; \( \text{jump height} = \frac{1}{8} \times \text{gravity} \times \text{flight time}^2 \). The results of the study revealed that the SJT compared to the jump platform system had a validity of \( r=0.99, p=0.001 \) and reproducibility of \( r=0.99, p=0.001 \), \( n=45 \) (Fonseca & Dantas, 2012). The SJT was determined to be a reliable and valid means to measure explosive strength and power.

Each participant maximally extended their right hand upward against a wall with both heels firmly planted on the ground to measure reach height. Participants were then instructed to maximally jump upwards using no approach and reach with their right hand to the highest point they could achieve. Maximal jump height was measured using the Vertec jump device. The difference between the max height jumped and reach height was recorded as the vertical jump.

**Vertec**

The Vertec (Sports Imports, Columbus, Ohio) was used in conjunction with the SJT to accurately measure maximal vertical jump in the participants. Participants started the SJT by standing directly underneath the vertec and were instructed to jump maximally touching the highest marker they could reach. Jump height was recorded by the highest point attained on the vertec device.

**Lactate Scout Blood Lactate Analyzer**

The Lactate Scout (SensLab, Leipzig, Germany) was a portable hand held research grade lactate analyzer and was used to measure blood lactate during rest, exercise, and the recovery interventions. The Lactate Scout used only 0.2μl of blood and required up to 3-10 s for complete analysis. Furthermore, the Lactate Scout used a enzymatic-amperometrical detection to accurately measure blood
lactate concentrations (mmol/L) for each participant. Research suggests it is more desirable to sample blood lactate from areas which are more distal to metabolically active tissues (Comeau, Adams, Church, Graves, & Lawson, 2011). However, Forsyth and Farrally (2000) discovered that blood lactate samples performed on the finger, toe, and earlobe were statistically similar during moderate to high intensity rowing exercise. Suggesting that blood lactate sample location may be irrelevant to the exercise protocol or metabolically active tissues (Forsyth & Farrally, 2000). In the present study the earlobe was chosen as the primary blood lactate sample site due to accessibility during the CWI intervention and location to active tissues.

Lactate sample procedures:

1. Insert disposable Lactate Scout test strip (SensLab, Leipzig Germany) into the Lactate Scout (SensLab, Leipzig, Germany) and ensure proper code is read.
2. Load lancing device with lancet and cock spring by pulling back on the rear.
3. Sanitize the sampling area (e.g. finger or earlobe) with a 70-90% ethyl or isopropyl alcohol swab and let air dry (HICPAC, 2008) (see Appendix D).
4. Press loaded lancing device firmly against the skin of the sampling area and release spring.
5. Remove device and wait until blood droplet forms on the skin surface.
6. Sample blood droplet by touching the tip of the disposable test strip to the blood droplet and wait 3 s for blood to be absorbed.
7. After sampling, clean punctured area with a 70-90% ethyl or isopropyl alcohol swab and apply bandage (HICPAC, 2008) (see Appendix D).

8. Discard disposable test strip, used lancet, protective gloves, and soiled alcohol swabs in the proper biohazard container.

Please note that during this process technician is wearing protective non-latex gloves at all times.

Lactate Scout Test Strip

The Lactate Scout test strips (SensLab, Leipzig, Germany) were used to acquire blood samples for lactate analysis by the Lactate Scout device. These test strips were disposable and were only used for one blood lactate sample analysis. Once the sample was completed the test strips were be discarded in the proper biohazard container.

Hydrotherapy Tank & Circulation Pump

The hydrotherapy tank and circulation pump (Whitehall Manufacturing Inc., La Puente, California) was used to administer the CWI recovery intervention to each participant. The tank allowed participants to be adequately submerged to their clavicle and the circulation pump maintained a consistent water temperature during the entire intervention. Once the intervention had been administered the hydrotherapy tank was filled with a 1 part 5.25%-6.15% sodium hypochlorite (e.g. household bleach) and 100 parts water solution (1:100 ratio) for 24 hr (HICPAC, 2008). This was performed to sufficiently disinfect the hydrotherapy tank and circulation pump after CWI intervention.
Sodium Hypochlorite

Sodium hypochlorite at concentrations of 5.25-6.15% (e.g., household bleach) was used (1:100 parts water solution) to disinfect all hydrotherapy equipment (HICPAC, 2008, pp. 39-42) (see Appendix D). The CDC suggests that a 1:100 parts 5.25-6.15% sodium hypochlorite solution is adequate for disinfecting surfaces that only come into contact with skin. Furthermore, the CDC stated that a 1:100 parts 5.25-6.15% sodium hypochlorite solution has been commonly used and is cleared to disinfect hydrotherapy tanks after human use (HICPAC, 2008).

Procedures

Before any forms, questionnaires, or research tests were administered approval from the Committee on the Protection of Human Subjects at California State University, Fresno was obtained. After approval five male participants from a collegiate club volleyball team volunteered to participate in the study. Each participant answered a Participant Medical & Demographics Questionnaire (PMDQ) outlining the contraindications for rectal thermometers and basic demographical information, as well as a Health & Fitness Facility Pre-participation Screening Questionnaire (HFFPSQ) evaluating maximal exercise readiness. All participants were cleared to participate in the study and perform maximal exercise according to the criteria outlined on both the PMDQ and HFFPSQ questionnaires. In addition, each participant read and signed an informed consent (ICF) outlining the risks, protections, and requirements of research involvement. These documents were obtained from each participant before any measurements and/or exercise trials began. All participants entered the study strictly on a volunteer basis and were notified of their right to withdraw from the study at any time.
Participants met on five separate occasions for 1-3 hr in the Kinesiology Departments; Human Performance Lab (HPL, South Gym, Room # 139) at the California State University, Fresno. On day 1, each participant met in the HPL to be briefed on all experimental procedures, and complete the pre-participation questionnaires and forms (e.g., HFFPSQ, PMDQ, & ICF).

During the first round of testing (days 2 & 3), the participants met in the HPL and rested for 1 hr before the start of the exercise trials. Each participant then warmed up using a stationary bike for 5 min (1.5kp @ 60rpm) and completed 10 body weight squats and 10 high knee jumps. After warming-up, each participant performed three repeated maximal SJT, and three repeated maximal IRTL1 in a gym setting at room temperatures of \( M=21.88°C, SD=0.52 \) and relative humidity of \( M=34.69\%, SD=3.96 \). Three min of rest was allotted between each SJT attempt and 10 min of rest was allotted between each IRTL1 attempt. Furthermore, the participants were also given 3 min of rest between the SJT and IRTL1. The three SJT attempts were averaged and reported as vertical jump (VJ) and the three IRTL1 attempts were averaged and reported as distance traveled (DT). The IRTL1 test protocol was regulated by the Team Beep Test software (TBT, Bitworks, United Kingdom) to minimize testing error. Once the exercise tests were completed each participant was randomly selected for one of two 15 min recovery interventions; a cold water immersion (CWI) or a passive recovery. Participants selected for the CWI recovery were submerged to the clavicle in \( M=14.28°C, SD=0.37 \) water using a hydrotherapy tank (Whitehall Manufacturing Inc., La Puente, California), and participants selected for the passive recovery were seated in a quiet room at temperatures of \( M=23.5°C, SD=0.58 \). After the recovery intervention was administered, participants returned 24 hr later (day 3) to retest exercise performance for the SJT and IRTL1. During
retesting, participants performed the same testing procedures as the previous day (three repeated maximal SJT, and three repeated maximal IRTL1), however no recovery intervention was administered.

During the second round of testing (days 4 & 5), participants repeated the same procedures as round 1, however the opposite recovery intervention was administered. The first round and second rounds of testing were separated by at least 1 week to minimize testing overlap.

In addition to the performance tests, each participant was subject to HR, BL, and CT measurements to assess physiological recovery after the exercise trials for both recovery interventions. These measurements were collected pre exercise (baseline), immediately post exercise, and during both of the recovery interventions (0, 5, 10, 15 min). Heart rate was measured using the FT7 wireless heart rate monitor (Polar, Kempele, Finland) fastened around the thorax, blood lactate was measured via the left earlobe using the Lactate Scout (SensLab, Leipzig, Germany), and core temperature was measured using a 1/8" by 4" DataTherm II disposable rectal thermometer (Geratherm Medical AG, Geschwenda, Germany). Lastly, indoor climate (relative humidity & temperature) was measured using the Perception II climate sensor (Davis Instruments, Hayward, California) and recorded for each exercise trial.

**Analysis**

Hypothesis one was analyzed using a univariate ANOVA to determine the differences in performance variables (e.g. SJT & IRTL1) via gain scores between the two level intervention. The second hypothesis was analyzed as the magnitude of change between the first and last measurement of each of the recovery variables (e.g., HR, BL, & CT) and differences in variable change between interventions
was processed using a univariate ANOVA. The level of significance was set to $\alpha < 0.05$, and descriptive data were analyzed and reported as mean ± mean $SD$. 
CHAPTER 4: RESULTS

Results

No significant differences were found between the CWI and Passive Recovery interventions for either the SJT ($p=0.19$) or the IRTL1 ($p=0.131$) (see Table 1). Vertical Jump measurements for the CWI intervention were ($M=21.74\text{ in}, SD=2.85$) pre intervention and ($M=22.38\text{ in}, SD=3.61$) post intervention, and Passive Recovery measurements were ($M=21.13\text{ in}, SD=3.9$) pre intervention and ($M=21.35\text{ in}, SD=3.61$) post intervention (see Figure 1). Furthermore, measurements for Distance Traveled during the CWI intervention were ($M=764.99\text{ m}, SD=681.94$) pre intervention and ($M=894.99\text{ m}, SD=745.12$) post intervention, and Passive Recovery measurements were ($M=916.66\text{ m}, SD=629.49$) pre intervention and ($M=903.33\text{ m}, SD=585.59$) post intervention (see Figure 2). These results did not support the hypothesis that a CWI intervention would significantly support exercise recovery potentially sustaining and/or improving exercise performance in athletes with EIH. However, the data presented in Figure 2 suggests that after the CWI intervention the participants performed better during the IRTL1 compared to the Passive Recovery.

Table 1

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Vertical Jump ± SD (in)</th>
<th>Distance Traveled ± SD (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Recovery</td>
<td>Pre: 21.13 ± 3.92</td>
<td>916.66 ± 629.49</td>
</tr>
<tr>
<td></td>
<td>Post: 21.35 ± 3.61</td>
<td>903.33 ± 585.59</td>
</tr>
<tr>
<td>CWI Recovery</td>
<td>Pre: 21.74 ± 2.85</td>
<td>764.99 ± 681.94</td>
</tr>
<tr>
<td></td>
<td>Post: 22.38 ± 3.61</td>
<td>894.99 ± 745.12</td>
</tr>
</tbody>
</table>

Gain Score

$p=0.19$                                     $p=0.13$
Figure 1. Graphical representation of SJT between recovery interventions.

Figure 2. Graphical representation of IRTL1 between recovery interventions.
Likewise, no significant differences were found between the recovery interventions and Heart Rate ($p=0.66$), Blood Lactate ($p=0.65$), or Core Temperature ($p=0.63$) (see Table 2). The magnitude of change for heart rate during the CWI intervention was ($M=66.75\text{bpm}$, $SD=21.13$) and during Passive Recovery was ($M=76.75\text{bpm}$, $SD=12.26$) (see Figure 3). The magnitude of change for blood lactate during the CWI intervention was ($M=4.78\text{mmol/l}$, $SD=3.21$) and during Passive Recovery was ($M=3.93\text{mmol/l}$, $SD=1.5$) (see Figure 4). The magnitude of change for core temperature during the CWI intervention was ($M=1.24\text{°C}$, $SD=0.92$) and during Passive Recovery was ($M=0.98\text{°C}$, $SD=0.47$) (see Figure 5). Again these results did not support the hypothesis that there would be a greater improvement in physiological recovery after a CWI intervention in athletes with EIH.

Table 2

**Passive Recovery vs. CWI Recovery (HR, BL, & CT)**

<table>
<thead>
<tr>
<th>Intervention</th>
<th>HR ± SD (bpm)</th>
<th>BL ± SD (mmol/L)</th>
<th>CT ± SD (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Recovery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>68.00 ± 13.29</td>
<td>1.35 ± 0.44</td>
<td>37.16 ± 0.37</td>
</tr>
<tr>
<td>Post Exercise</td>
<td>175.50 ± 5.69</td>
<td>7.10 ± 3.55</td>
<td>38.55 ± 0.34</td>
</tr>
<tr>
<td>0 min recovery</td>
<td>111.75 ± 3.86</td>
<td>6.13 ± 3.88</td>
<td>38.33 ± 0.25</td>
</tr>
<tr>
<td>5 min recovery</td>
<td>102.25 ± 9.50</td>
<td>4.68 ± 2.55</td>
<td>37.95 ± 0.13</td>
</tr>
<tr>
<td>10 min recovery</td>
<td>102.50 ± 12.23</td>
<td>3.73 ± 2.38</td>
<td>37.73 ± 0.20</td>
</tr>
<tr>
<td>15 min recovery</td>
<td>98.75 ± 9.21</td>
<td>3.18 ± 2.22</td>
<td>37.57 ± 0.22</td>
</tr>
<tr>
<td>CWI Recovery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>73.50 ± 9.95</td>
<td>1.55 ± 0.79</td>
<td>37.16 ± 0.23</td>
</tr>
<tr>
<td>Post Exercise</td>
<td>156.25 ± 22.95</td>
<td>7.75 ± 4.89</td>
<td>38.47 ± 0.67</td>
</tr>
<tr>
<td>0 min recovery</td>
<td>122.00 ± 2.94</td>
<td>6.40 ± 5.54</td>
<td>38.20 ± 0.55</td>
</tr>
<tr>
<td>5 min recovery</td>
<td>98.25 ± 3.20</td>
<td>4.60 ± 3.09</td>
<td>37.53 ± 0.98</td>
</tr>
<tr>
<td>10 min recovery</td>
<td>91.75 ± 5.62</td>
<td>3.48 ± 2.04</td>
<td>37.36 ± 0.77</td>
</tr>
<tr>
<td>15 min recovery</td>
<td>89.80 ± 7.77</td>
<td>2.98 ± 1.76</td>
<td>37.23 ± 0.69</td>
</tr>
</tbody>
</table>

**Magnitude of Change**

$p=0.66$ $p=0.65$ $p=0.63$
Figure 3. Graphical representation of heart rate during the recovery interventions.

Figure 4. Graphical representation of blood lactate during the recovery interventions.
Figure 5. Graphical representation of core temperature during the recovery interventions.
CHAPTER 5: CONCLUSION

Discussion

All of the participants in this study successfully reached core temperatures which qualified as EIH during both the first and second rounds of testing. Hyperthermia, however, did not seem to affect the outcome of a CWI intervention as White and Wells and Nybo suggested. The results indicate that a CWI recovery (14.28°C±0.37 for 15 min) between repeated maximal high intensity sprint interval exercise (IRTL1) and repeated maximal vertical jump (SJT) did not significantly affect recovery or performance the following day compared to passive recovery. Rupp et al. found similar results and noted that there was no change in successive HIIT performance in 22 trained soccer athletes after a CWI intervention. Pointon et al. also concluded that a CWI intervention did no significantly affect the outcome of sprint performance (e.g. distance traveled) in 10 male collegiate athletes. Even though no statistical significant differences were found between the recovery interventions and the performance variables, the post-CWI performance measurements for the IRTL1 showed a positive trend in performance recovery. Similarly, Brophy-Williams et al. discovered that there were significant increases in exercise performance 24 hr after a CWI intervention in eight collegiate athletes performing sprint intermittent recovery tests.

In addition, no significant differences were discovered between the magnitude of change in physiological recovery variables and the recovery interventions. Previous studies noted that a CWI intervention may reduce peripheral edema (via hydrostatic pressure & vasoconstriction) and increase venous return improving cardiac function (Leeder et al., 2012; Vaile et al., 2011; White & Wells, 2013). However, heart rate did not decline faster after the CWI
intervention compared to the passive recovery. Likewise Yanagisawa et al. reported better blood lactate clearance after a CWI intervention due to improved blood profusion to active tissues, but no significant differences in blood lactate where recorded between the recovery interventions. Given that better blood lactate clearance was contingent on improved cardiac efficiency, it is not surprising that blood lactate showed little to no change between recovery interventions.

Lastly, no significant differences were discovered in core temperature measurements between the recovery interventions. McDermott et al. concluded that cooling baths of $\approx 14^\circ C$ for 15 min were adequate in rapidly reducing core temperatures in hyperthermic individuals. However, core temperature dropped at similar rates during both interventions. Similar cooling rates may be attributed to the interaction between the CWI bath and the participants fat and fat free mass (Otte, Merrick, Ingersoll, & Cordova, 2002). Otte et al. discovered that subcutaneous fat thickness and exposed surface area may play a large role in the rate of heat loss during cooling interventions like CWI.

**Limitations**

Several limitations were encountered during the course of this study. Due to high participant attrition only four participants completed the entirety of the study significantly lowering the statistical power of the results.

Secondly, the gymnasium in which all testing was completed was in use during both the first and second round of testing. Therefore, all data were collected between the hours of 11pm-8am. This may have negatively affected motivation and contributed to excess fatigue during the course of the exercise trials.

Thirdly, the participants used in the study lacked training and specific experience for the IRTL1 test. Given the nature of their sport (volleyball), the
participants were unaccustomed to repeated maximal sprint exercise which may have increased perceptual fatigue and led to premature termination of the IRTL1 tests.

Lastly, participant height, body mass, body composition, and level of fitness varied tremendously which may have affected the performance outcome as well as the rate of cooling during the CWI. If the rate of cooling from the CWI intervention was inadequate, changes in the physiological recovery between the recovery interventions may have also been relatively unaffected.

Future Directions

The use of a CWI intervention after high intensity exercise in athletes with EIH may still have the potential to benefit exercise recovery. Given a larger participant pool significance may have been found in the performance variables (SJT & IRTL1) and physiological recovery.

In addition it may be beneficial to recruit collegiate athletes who regularly perform maximal sprint type exercise. This may potentially decrease participant variability in the sprint performances leading to better physical effort during the three IRTL1 tests.

Furthermore, closer evaluations of anthropometric measurements (e.g. body mass, body fat, & height) may be useful in determining a more appropriate cooling intervention via CWI. Otte et al. (2002) describes how subcutaneous skin thickness (body fat) can drastically affect the rate of cooling during cryotherapy treatments. Future studies may want to implement an alternative or additional CWI intervention at lower temperatures or for longer durations depending the participants' specific anthropometric profiles. This may increase the rate of cooling
on core temperature after maximal sprint exercise which could impose a greater effect/change on sports performance and physiological recovery variables.

**Conclusion**

Leeder et al. (2012) and White and Wells (2013) both agree that the cooling effects of a CWI intervention after high intensity exercise in the heat may contribute to faster recovery of sports performance. However, the results of this study did not find evidence which support the use of a CWI recovery after high intensity exercise (SJT & IRTL1) in athletes with EIH. Still it is important to note that EIH negatively influences prolonged or repeated exercise especially when performed in the heat (Bouchama & Knochel, 2002; Nybo, 2008; Nybo & Nielsen, 2001). In tournament style play many athletes do not have the ability to adequately cool body temperatures between consecutive matches. It is therefore important to evaluate mechanisms like CWI recoveries in athletes with EIH to understand the effects it may have on exercise recovery, performance, and even health. To the authors knowledge EIH and cooling strategies for sports performance recovery remain relatively unstudied. Of the research that does exist the results are dissimilar and contradictory. Thus, it is important for future research to implement studies which will better define this field of study.
REFERENCES
References


APPENDIX A: INFORMED CONSENT
Informed Consent

Purpose:
You have been invited to participate in a research study conducted by Dr. Tim Anderson and Eric Middleton in the Department of Kinesiology at California State University, Fresno. This study examines sports performance recovery in athletes with exercise induced increase in body temperature (hyperthermia). During tournament play, athletes are required to optimally perform game after game. However, most athletes experience muscular fatigue and/or soreness between matches and are unable to maintain peak performance. In addition, tournament play can lead to exercise induced hyperthermia which may further handicap sports performance and slow recovery. Thus the purpose of this study is to evaluate a recovery technique to determine its effectiveness at diminishing exercise induced hyperthermia and improving performance recovery. You have been selected as a possible candidate for this study because you are an athlete on a competitive collegiate club sport.

Procedures:
If you choose to participate, you will enter a series of maximal exercise tests and measurements necessary to assess exercise induced hyperthermia and performance recovery. The procedure requires each participant to meet on five separate days for 1-3 hr each session to complete all testing. Testing will be conducted in the Kinesiology Departments Human Performance Lab (South Gym, Room # 139) at the California State University, Fresno. On day 1, you will meet in the Human Performance Lab (HPL) to be briefed on the experimental procedures, complete a Health & Fitness Facility Pre-participation Screening Questionnaire, and become familiar with the exercise tests. Day 1 testing should last no longer than 1 hr. On day 2, you will perform a maximal vertical jump test, followed by an exhaustive exercise performance test. After these tests, you will receive one of two recovery treatment options; cold water immersion for 15 min or passive recovery technique for 15 min. You will perform both recovery methods on different test days. In addition, you will complete tests to measure your level of performance and recovery. These tests include; heart rate, blood lactate, core temperatures, and perceived recovery.

Potential Risks & Discomforts:
This is an at risk study due to your requirement to perform a maximal exercise test. In addition, you may experience acute fatigue, muscle soreness, dizziness, headaches, nausea, light headedness, vomiting, chills, increases in heart rate, shortness of breath, hyperthermia, hypothermia, muscular and/or skeletal injury, injury to rectal mucous-membrane, and potentially death. In addition, core
temperatures will be measured rectally by self-administering a small flexible thermometer (≈1/8" Diameter × ≈4" Length) into the rectum. This method may increase your risk of bacterial and/or viral infections; however, extensive precautions have been taken to minimize all of the risks noted above to ensure your safety. The Committee on the Protection of Human Subjects at California State University, Fresno has reviewed and approved the procedures of this study. Participation in this study is voluntary. Your decision whether or not to participate will not prejudice your future relations with California State University, Fresno. You are under no obligation to be a participant and, if at any time, you do not feel comfortable with a physical test or question being asked, you may skip the test or questionnaire item or withdraw from the study without any penalty from California State University, Fresno, the Department of Kinesiology, or its affiliates.

Medical Disclosure:  
As a precautionary measure to ensure your safety, you will be asked to disclose any medical and/or health issues you are aware of or have experienced which may affect your ability to safely perform the study’s tests. Some of these issues may include but are not limited to; heart problems, chest pain, high or low blood pressure, fainting, shortness of breath, metabolic disorders such as diabetes and/or hyper or hypothyroidism, hemophilia, intestinal conditions, and discomfort exercising. In addition, you will also be asked to disclose any and all prescription and non-prescription medications you are currently taking. It is your responsibility to abide by these requests to fully ensure your safe participation. Your personal health information will be reviewed only by the study’s researchers and WILL NOT be shared with your coaches, teammates or any other persons.

Other Research Requirements:  
During testing, you will be asked to maintain similar eating and sleeping habits for 48 hr as well as restrict all food and drink 1 hr before the start of each testing trail. However, once testing begins you will be allowed to drink room temperature water freely. Furthermore, ingestion of alcohol, stimulants, and any pain, anti-inflammatory, and blood thinning medications (e.g. caffeine, ibuprofen, aspirin, and other NSAIDS) will be prohibited 24 hr prior to and during participation. In addition you will also be asked to abstain from all exercise 24 hr prior to and during all exercise testing. These measures must be taken to accurately measure the variables in this study.

Potential Benefits:  
There is no financial compensation for study participants. However, Eric Middleton will donate his time and expertise as a strength and conditioning professional to the club sport team. Also, participants may gain better understanding of and/or experience an effective sport performance recovery after
exercise induced hyperthermia. However, there is no guarantee that participants will receive the later benefits.

Participant Rights, Confidentiality, & Anonymity:

All information you give will be kept strictly confidential by the study’s investigator. Your privacy will be protected to the maximum extent allowable by law. You will not be identifiable in any report of this research. Only group data will be presented in write-ups and discussions of this study. However, to maintain your anonymity it is advised that you do not write your name on any scales, forms, or questionnaires unless asked. Results of the study may be made available to you upon request and within the restrictions outlined on this form.

Questions:

If you have further questions or concerns regarding your participation in this study, please contact Dr. Tim Anderson at tima@csufresno.edu or (559)-278-2203, or Mr. Eric Middleton at emiddle409@mail.fresnostate.edu or (559)-908-5545. Questions regarding the rights of research subjects may be directed to Dr. Constance Jones, Chair, CSUF Committee on the Protection of Human Subjects at (559) 278-4468.

Consent:

By signing this form you will adhere to all of conditions outlined above and voluntarily agree to participate in this study.

_____________________________ ________________________
Participants Name: Signature: Date:

Please return this form to:
Dr. Tim Anderson & Eric Middleton,
Department of Kinesiology
5275 N. Campus Dr., M/S SG28, Fresno, CA 93740
APPENDIX B: PARTICIPANT MEDICAL & DEMOGRAPHICS QUESTIONNAIRE (PMDQ)
Participant Medical & Demographics Questionnaire

Please fill out and answer all sections below as best you can:

Male □ Female □ Name:________________________ Date:________ I.D.#:_____

Email:_________________________________ Phone:____________________

Age:______ Height (ft):_______ Weight (lbs):_______ Body Fat (%):_____

Ethnicity: □ Aboriginal □ African
□ Asian (East & Southeast) □ Asian (South)
□ Caribbean □ European
□ Latin, Central, & South American □ Middle Eastern
□ Pacific Islander
□ Other (please specify):_________________

1. How long have you been competitively playing volleyball?

<1 year □ 1-2 years □ 3-4 years □ ≥5 years □

2. Are you currently an active member of the CSUF, Men’s Club Volleyball team?

Yes □ No □

3. Have you been attending the CSUF, Men’s Club Volleyball team practices regularly (at least once per week) for the past two months?

Yes □ No □

4. Have you been attending the CSUF, Men’s Club Volleyball team strength and conditioning workouts (at least once per week) for the past month?

Yes □ No □
5. Do you have any metabolic disorders? (e.g. diabetes, hypothyroidism, hyperthyroidism, etc.)

   Yes □ No □

6. Do you have any medical and or health issues that may affect you ability to perform maximal or exhaustive exercise? (e.g. asthma, high blood pressure, etc.)

   Yes □ No □

   If "Yes" please list:

   ________________________________________________________________

7. Do you take any prescription of non-prescription medications? (e.g. aspirin, ibuprofen, Aleve, insulin, blood thinners etc.)

   Yes □ No □

   If "Yes" please list:

   ________________________________________________________________

8. Are there any other reasons you feel unconfident (medical or not) in performing maximal or exhaustive exercise?

   Yes □ No □

   If "Yes" please explain:

   ________________________________________________________________

9. You are aware that you have a pre-existing heart condition?

   Yes □ No □

   If "Yes" please explain:

   ________________________________________________________________
APPENDIX C: HEALTH & FITNESS FACILITY PRE-PARTICIPATION SCREENING QUESTIONNAIRE (HFFPSQ)
AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health needs by marking all true statements.

History
You have had:
- ___ A heart attack
- ___ Heart surgery
- ___ Cardiac catheterization
- ___ Coronary angioplasty (PTCA)
- ___ Pacemaker/implantable cardiac defibrillator/rhythm disturbance
- ___ Heart valve disease
- ___ Heart failure
- ___ Heart transplantation
- ___ Congenital heart disease

If you marked any of the statements in this section, consult your physician or other appropriate healthcare provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Other health issues
- ___ You have diabetes
- ___ You have or asthma other lung disease.
- ___ You have burning or cramping in your lower legs when walking short distances.
- ___ You have musculoskeletal problems that limit your physical activity.
- ___ You have concerns about the safety of exercise.
- ___ You take prescription medication(s).
- ___ You are pregnant.

Symptoms
- ___ You experience chest discomfort with exertion.
- ___ You experience unreasonable breathlessness.
- ___ You experience dizziness, fainting, blackouts.
- ___ You take heart medications.

Cardiovascular risk factors
- ___ You are a man older than 45 years.
- ___ You are a woman older than 55 years, you have had a hysterectomy, or you are postmenopausal.
- ___ You smoke, or quite within the previous 6 mo.
- ___ Your BP is greater than 140/90.
- ___ You don't know your BP.
- ___ You take BP medication.
- ___ Your blood cholesterol level is >200 mg/dl.
- ___ You don't know your cholesterol level.
- ___ You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
- ___ You are physically inactive (i.e., you get less than 30 min. of physical activity on at least 3 days per week).
- ___ You are more than 20 pounds overweight.

If you marked two or more of the statements in this section, you should consult your physician or other appropriate healthcare provider before engaging in exercise. You might benefit by using a facility with a professionally qualified exercise staff to guide your exercise program.

___ None of the above is true.

You should be able to exercise safely without consulting your physician or other healthcare provider in a self-guided program or almost any facility that meets your exercise program needs.


www.acsm.org/pb-core-template-journal-media/0998c.htm
APPENDIX D: CDC; GUIDELINES FOR DISINFECTION & STERILIZATION IN HEALTHCARE FACILITIES, 2008 (METHODS OF STERILIZATION & DISINFECTION)
Table 1. Methods of sterilization and disinfection.

<table>
<thead>
<tr>
<th>Critical items (will enter tissue or vascular system or blood will flow through them)</th>
<th>Sterilization</th>
<th>High-level (semicritical items; except dental) will come in contact with mucous membrane or nonintact skin</th>
<th>Disinfection</th>
<th>Intermediate-level (some semicritical items and noncritical items) will come in contact with intact skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object</td>
<td>Procedure</td>
<td>Exposure time (12-30 min at 220°F)</td>
<td>Procedure (exposure time ≥ 1 m)</td>
<td>Procedure (exposure time ≥ 1 m)</td>
</tr>
<tr>
<td>Smooth, hard Surface</td>
<td>A</td>
<td>MR</td>
<td>D</td>
<td>K</td>
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<tr>
<td>B</td>
<td>MR</td>
<td>E</td>
<td>L⁵</td>
<td>L</td>
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<tr>
<td>C</td>
<td>MR</td>
<td>F</td>
<td>M</td>
<td>M</td>
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<tr>
<td>D</td>
<td>10 h at 20-25°C</td>
<td>H</td>
<td>N</td>
<td>N</td>
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<tr>
<td>E</td>
<td>6 h</td>
<td>I⁵</td>
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<tr>
<td>G</td>
<td>12 m at 50-56°C</td>
<td>J</td>
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<td>H</td>
<td>3-8 h</td>
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<td></td>
<td></td>
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<tr>
<td>Rubber tubing and catheters⁶,⁷</td>
<td>A</td>
<td>MR</td>
<td>D</td>
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<tr>
<td>B</td>
<td>MR</td>
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<td>12 m at 50-56°C</td>
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<td>H</td>
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<tr>
<td>Polyethylene tubing and catheters⁶,⁷</td>
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<td>MR</td>
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<td>3-8 h</td>
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<tr>
<td>Lensed instruments⁶</td>
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<td>B</td>
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<td>3-8 h</td>
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<tr>
<td>Thermometers (oral and rectal)⁵</td>
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<tr>
<td>Hinged instruments⁵</td>
<td>A</td>
<td>MR</td>
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<td>3-8 h</td>
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</table>

Modified from Rutaia and Simmons, ⁶.⁷.⁸.⁹. The selection and use of disinfectants in the healthcare field is dynamic, and products may become available that are not in existence when this guideline was written. As newer disinfectants become available, persons or committees responsible for selecting disinfectants and sterilization processes should be guided by products cleared by the FDA and the EPA as well as information in the scientific literature.
A. Heat sterilization, including steam or hot air (see manufacturer’s recommendations, steam sterilization processing time from 3-30 minutes).
B. Ethylene oxide gas (see manufacturer’s recommendations, generally 1-8 hours processing time plus aeration time of 8-12 hours at 50-60°C).
C. Hydrogen peroxide gas plasma (see manufacturer’s recommendations for internal diameter and length restrictions, processing time between 45-72 minutes).
D. Glutaraldehyde-based formulations (2% glutaraldehyde, caution should be exercised with all glutaraldehyde formulations when further in-use dilution is anticipated); glutaraldehyde (1.12%) and 1.93% phenol/cresol. One glutaraldehyde-based product has a high-level disinfection claim of 5 minutes at 35°C.
E. Ortho-phthalaldehyde (OPA) 0.5%.
F. Hydrogen peroxide 7.5% (will corrode copper, zinc, and brass).
G. Peracetic acid, concentration variable but 0.2% or greater is sporicidal. Peracetic acid immersion system operates at 50-55°C.
H. Hydrogen peroxide (7.30%) and 0.23% peracetic acid, hydrogen peroxide 1% and peracetic acid 0.08% (will corrode metal instruments).
I. Wet pasteurization at 70°C for 30 minutes with detergent cleaning.
J. Hypochlorite, single use chlorine generated on-site by electrolyzing saline containing >650-675 active free chlorine; (will corrode metal instruments).
K. Ethyl or isopropyl alcohol (70-90%).
L. Sodium hypochlorite (5.25-6.15% household bleach diluted 1:50 provides >100 ppm available chlorine).
M. Phenolic germicidal detergent solution (follow product label for use-dilution).
N. Iodophor germicidal detergent solution (follow product label for use-dilution).
O. Quaternary ammonium germicidal detergent solution (follow product label for use-dilution).
MR. Manufacturer’s recommendations.
NA. Not applicable.

1 See text for discussion of hydrotherapy.
2 The longer the exposure to a disinfectant, the more likely it is that all microorganisms will be eliminated. Follow the FDA-cleared high-level disinfection claim. Ten-minute exposure is not adequate to disinfect many objects, especially those that are difficult to clean because they have narrow channels or other areas that can harbor organic material and bacteria. Twenty-minute exposure at 25°C is the minimum time needed to reliably kill M. tuberculosis and nontuberculous mycobacteria with a 2% glutaraldehyde. Some high-level disinfectants have a reduced exposure time (e.g., ortho-phthalaldehyde at 12 minutes at 20°C) because of their rapid activity against mycobacteria or reduced exposure time due to increased mycobacterial activity at elevated temperature (e.g., 2.5% glutaraldehyde at 5 minutes at 35°C, 0.55% OPA at 5 min at 25°C in automated endoscope reprocessor).
3 Tubing must be completely filled for high-level disinfection and liquid chemical sterilization; care must be taken to avoid entrapment of air bubbles during immersion.
4 Material compatibility should be investigated when appropriate.
5 A concentration of 1000 ppm available chlorine should be considered where cultures or concentrated preparations of microorganisms have spilled (5.25% to 8.15% household bleach diluted 1:50 provides > 1000 ppm available chlorine). This solution may corrode some surfaces.
6 Pasteurization (wet or disinfectant) of respiratory therapy or anesthesia equipment is a recognized alternative to high-level disinfection. Some data challenge the efficacy of some pasteurization units.
7 Thermostability should be investigated when appropriate.
8 Do not mix rectal and oral thermometers at any stage of handling or processing.
9 By law, all applicable label instructions on EPA-registered products must be followed. If the user selects exposure conditions that differ from those on the EPA-registered products label, the user assumes liability from any injuries resulting from off-label use and is potentially subject to enforcement action under FIFRA.
APPENDIX E: YO-YO INTERMITTENT RECOVERY TEST LEVEL 1 (IRT1)
Intermittent Recovery Test Level 1 (IRTL1) Protocol

Sprint: $2 \times 20 \, m$, Rest 10 s (Repeat)

Note: 1 lap = 40 m (2 $\times$ 20 m sprints)

Participants continued to progress through each stage until they were unable to match the running speed of a specific stage. When they failed to keep up with the pace of a stage twice in a row the test was terminated and distance traveled was recorded.

NOTE: The IRTL1 was performed on a gymnasium hardwood floor not on a treadmill

<table>
<thead>
<tr>
<th>Stage</th>
<th>Laps</th>
<th>Run Speed (Km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>11.5</td>
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<td>3</td>
<td>2</td>
<td>13</td>
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<td>4</td>
<td>3</td>
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<td>18.5</td>
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<td>15</td>
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Fresno State

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