Postexercise recovery, referring to a period of psychological and physical regeneration,1 is a vital part of any training program, as it can allow athletes to overcome the demands of training and competition. Muscle damage can have a limiting effect on muscle performance in the days after exercise.2 Recovery should be prioritized for athletes competing regularly (ie, weekly), as it contributes to the minimization of fatigue between competitions.3 Strategies that optimize recovery after intense activity may help reduce physical-performance decrements after exercise and therefore benefit subsequent training and athletic performance.

Cold-water immersion (COLD) and contrast water therapy (CWT) are recovery methods commonly employed in athletic settings.4–9 It has been suggested that both can help reduce fatigue between exercise bouts,1 alleviate symptoms of exercise-induced muscle soreness,6,10,11 and attenuate postexercise power and strength reductions.6,10 Reductions in edema, localized swelling, and indices of exercise-induced muscle damage have also been attributed to COLD.11,12

There is inconsistent evidence concerning the effects of water immersion on postexercise recovery in team sport, but a total immersion time of at least 10 minutes for COLD and CWT may enhance the effectiveness of these interventions. After a soccer game, 10 minutes of COLD (1 × 10 min, 10°C) enhanced recovery of 20-m-sprint performance and squat and countermovement jumps.4 In netballers, COLD (2 × 5 min, 9.3°C) helped ameliorate declines in 20-m repeat-sprint time and jump performance.7 Multiple exposures of 10 minutes or more can also assist recovery. After simulated team-sport running, multiple COLD (2 × 5 min, 10°C) and CWT (3 × 2 min, 10°C alternating with 3 × 2 min, 40°C) exposures reduced soreness, with COLD also facilitating a more rapid return of 20-m-sprint performance.6

Investigations using less than 10-minute immersions have demonstrated mixed results. A 5-minute COLD protocol (5 × 1 min, 10°C) did not affect physical performance, indices of muscle damage, or inflammation between successive matches in high-performance junior soccer players.9 In rugby, COLD (1 × 5 min, 10–12°C) had a detrimental effect on sprint performance,13 while CWT (3 × 1 min, 8–10°C alternating with 3 × 1-min...
showers, 38°C) had little effect on 40-m repeat-sprint performance. Conversely, 5 minutes of COLD (5 × 1 min, 11°C) assisted restoration of physical performance during a basketball tournament, while in netballers CWT (5 × 1-min, 9.7°C alternating with 5 × 2-min shower, 39.1°C) helped restore drop-jump performance and 20-m repeat-sprint time. These results lend support to the effectiveness of such therapy and the use of longer submersion times. Indeed, a recent review established that 14 to 15 minutes of COLD or CWT can improve performance, and the author recommends that at least 10 minutes of immersion be used.

COLD may promote recovery more quickly than CWT, as exposure to cold temperatures induces a number of physiological changes. These include analgesia, reductions in fluid diffusion, vascular permeability and edema, decreased localized vasoconstriction, and reduced acute inflammatory responses resulting from muscle damage. Conversely, the application of heat may be detrimental, as it can increase the inflammatory response and edema and therefore potentially decrease CWT’s effectiveness when compared with COLD. This was demonstrated when COLD ameliorated declines in repeat-sprint ability, muscle soreness, and leg strength more effectively than CWT in team-sport running. In netballers, COLD was more effective at reducing soreness and jump and sprint decrements between training sessions.

A lack of consistency in immersion durations employed in the same team-sport investigation makes it difficult to compare the effects of COLD and CWT. This may lead to confusion and/or difficulty for athletes and practitioners in deciding which protocol to use and how long individuals need to be immersed to obtain the greatest benefits. This is compounded by a lack of dose-response studies in team-sport athletes.

Australian football (AF) is a high-intensity intermittent full-contact team sport. It requires a combination of ball skills, speed, and athleticism and places high demands on a player’s prolonged running capacity, particularly high-intensity running. As such, in-game fatigue and subsequent muscle soreness and damage must be overcome by players. Recovery may play a vital role in this.

The difficulty in definitively determining the efficacy of water immersion for team-sport recovery has been come from the predominant use of simulated running or tournament scenarios as exercise stressors rather than matches or training. For a sport like AF, tournaments are uncommon, and the direct applicability of simulated running is questionable. It does not provide the same chaotic running patterns and is characterized by the absence of game-specific movements such as jumping or kicking. It also lacks the presence of a ball, an opponent, direct physical contact, and game or training pressures. Therefore, making an informed decision on water-based interventions using these data is difficult. Recovery after a game of AF has been investigated, but the results of a hot (5 × 2-min shower, 45°C) and cold (4 × 1 min, 12°C) recovery or pool recovery session directly postgame did not significantly enhance physical recovery over performing a next-day pool recovery session. Although water recovery after an AF game has been previously investigated, the efficacy of a single exposure to COLD or CWT immediately after AF activity is lacking, as are data on the use of water immersion per se immediately after AF training. During an AF season, players are generally expected to train 24 to 72 hours after their previous session, while during the preseason this is likely to be less than 24 hours. We believe that acute posttraining recovery may enable athletes to better prepare for their next training stimulus.

This study aimed to investigate the effectiveness of immediate and consistent COLD and CWT immersion times on recovery of physical and psychometric performance after AF training. We aimed to do this given the inconsistency in COLD and CWT immersion times in team sports and the limited research on COLD and CWT recovery in AF. We hypothesized, first, that AF training would lead to reduced physical capacity, as well as increased fatigue and soreness over a 48-hour period. Second, we believed that an acute, single exposure to both COLD and CWT would promote recovery more effectively than a passive recovery after AF training. We further hypothesized that COLD would be more effective than CWT as an acute recovery intervention after AF training.

**Methods**

**Subjects**

Fourteen professional male AF players (age 20.9 ± 3.3 y, body mass 79.6 ± 6.7 kg, height 186 ± 7.2 cm) with at least 4 years of specific AF training volunteered and provided written informed consent to participate in this 3-week study. All players were injury and illness free throughout the investigation. The study was approved by the Victoria University Human Research Ethics Committee and conformed to the Declaration of Helsinki.

**Design**

This counterbalanced crossover study investigated the effectiveness of 2 commonly used water-based recoveries after a midweek preseason AF training session.

Repeat-sprint ability (RSA), jump performance (countermovement jump and squat jump), perceived soreness, and fatigue were measured 45 minutes before training and immediately after training. Soreness and fatigue were measured after 1 hour, with all measures repeated 24 and 48 hours posttraining. Immediately after posttraining measures, all players undertook 1 of 3 recovery protocols: passive recovery (PAS), COLD, or CWT. During week 1, all players undertook PAS. This was unavoidable and mandated by the football club due to continuing facility construction. In week 2, COLD or
CWT was randomly assigned, with players undertaking the opposing recovery during week 3.

During the 48 hours after standardized training, players only undertook their prescribed recovery intervention and participated in no further physical training.

**AF Training**

Training took place at the same time and day over 3 consecutive weeks in similar environmental conditions (week 1, 24.5°C; week 2, 24.0°C; week 3, 24.2°C) and was replicated and standardized for time, load, and distance covered in drills. This was the main weekly football session and took place 48 hours after the previous training session. Training consisted of a 10-minute standard jog warm-up; 30-minute standardized skill development consisting of kicking, handball, and positioning drills; and 4 × 2.5-minute small-sided games interspersed with 2.5-minute rests. Small-sided games involved 2 groups of 8 players playing a hand passing game on a 25 × 15-m pitch. Goals were placed at each end, with the highest-scoring team winning. Players were encouraged verbally by coaches throughout. Training was noncontact; this type of team-sport training has proved to be a reliable option for assessing team-sport performance.20 Small-sided games were a regular part of the training program at this point of the preseason. Players had partaken in them on numerous occasions and were familiar with the demands and the setup.

Immediately after training was completed, all players headed directly into the testing facility (100 m away) for posttraining testing. This was to avoid their cooling down before postexercise measures.

**Psychometric Measures**

Training intensity was measured via rating of perceived exertion. This measure has previously been considered a good indicator in team sport of global internal load.21 Directly posttraining, players rated the global intensity of sessions based on a modified Borg scale of 1 to 10.22 Perceived fatigue and muscle soreness were assessed using a visual analog scale.23 Players were asked to indicate their soreness and fatigue on an unmarked horizontal line (100 mm in length) with no pain/no fatigue and very-severe pain/very-severe fatigue at opposing ends.

**Jump Performance**

Jump performance was assessed on completion of the psychometric measures. After a 5-minute standardized warm-up consisting of cycling and dynamic stretching, players performed several submaximal practice jumps. Testing then commenced with 2 squat jumps separated by 15 seconds. Players started with hands on hips in a fully upright position, dipped downward to a self-selected depth, then jumped as high as possible without pausing. The mean of the 2 jumps was then calculated, and jump performance was assessed through the ratio of flight time to contraction time. This measure has been demonstrated as the most sensitive and useful variable to assess neuromuscular fatigue in elite AF players.24 Trials were performed on a commercially available force plate (400 Series isometric force plate, Fitness Technology, Adelaide, Australia) connected to computer software (Ballistic Measurement System, Fitness Technology) capable of recording vertical ground-reaction forces.

**RSA Testing**

Within 90 seconds of concluding their jumps, players undertook an RSA test consisting of 6 × 20-m maximal sprints departing every 30 seconds. Sprints were conducted in an indoor stadium on a wooden floor. Each sprint involved a stationary start, with players reacting to a starting signal. Players walked back to the start position between sprints ready to commence their next effort. They performed 2 practice sprints before testing. Total time (sum of 6 sprints) was recorded using wireless single-beam light gates (Smart Speed, Fusion Sport, Grabba International Pty Ltd, Queensland, Australia). Total sprint time was used, as it has previously been reported as a reliable method of presenting repeat-sprint data.25

**Recovery Interventions**

Within 12 minutes of completing training and immediately on completion of the psychometric and physical testing, all athletes commenced their assigned recovery intervention. During COLD and CWT, players were seated with legs stretched out and immersed up to their xiphoid process. COLD involved players being submerged in tubs in 12°C water for 14 consecutive minutes. CWT required players to alternate between 1-minute hot- (38°C) and 1-minute cold-water (12°C) immersion for 7 cycles (total of 14 min). Hot and cold tubs (iCool Australia Pty Ltd, Queensland, Australia) were placed next to each other to minimize time spent changing between tubs (3 s). Heating and cooling units attached to the tubs measured and adjusted the water temperature to maintain the desired temperature. The PAS group was seated for 14 minutes with minimal movement in a posture similar to that of the immersed groups.

**Statistical Analysis**

Data are expressed as mean ± SD and effect size (ES) ± 90% confidence intervals (CI). Magnitude of change was calculated using ES ± 90% CI and percentage change using a custom spreadsheet. Repeat-sprint and jumps data were log transformed to reduce bias due to nonuniformity of error. Effects were characterized for their practical (clinical) significance. ES was assessed
using the following criteria: <0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large, and >2.0 very large.26 A substantial change was accepted when there was more than 75% likelihood that the true value of the standardized mean difference was greater than the smallest worthwhile (substantial) change. Raw data and change in means were reported for soreness and fatigue.

**Results**

Pretraining and posttraining psychometric and physical-performance data are presented in Table 1. Table 2 indicates change in mean and percentage change differences for soreness, fatigue, and physical performance between interventions. Figure 1 indicates change in mean scores between interventions for psychometric measures. Figure 2 indicates percentage change between interventions for physical-performance measures. Training intensity was comparable between groups over the 3 weeks (PAS 7.1 ± 1.1, COLD 7.0 ± 1.0, and CWT 7.1 ± 1.0).

**Acute Response to AF Training**

Immediately after training, acute decreases in sprint and jump performances were evident along with increased perceptions of soreness and fatigue, with no clear differences between groups (Table 1). Muscle soreness increased for all groups (PAS 2.69 ± 0.84, CWT 1.39 ± 0.32, and COLD 2.50 ± 0.39), as did perceived fatigue (PAS 4.77 ± 0.74, CWT 2.82 ± 0.49, and COLD 2.75 ± 0.41). Although results were unclear, jump performance decreased slightly for all groups. Sprint times deteriorated similarly for PAS (1.10 ± 0.35), CWT (0.71 ± 0.21), and COLD (0.80 ± 0.24).

**Response to AF Training Over 48 Hours**

Declines in performance and psychometric measures persisted for PAS during the 48-hour posttraining period (Table 1). Muscle soreness rose at 1 hour (3.21 ± 0.87), increased markedly at 24 hours (5.86 ± 0.65), and remained elevated at 48 hours (4.28 ± 0.58). Similarly, perceived fatigue remained high at 1 (3.93 ± 1.11), 24 (2.75 ± 1.07), and 48 hours (2.96 ± 0.77). Jump performances were slightly blunted immediately posttraining and remained so throughout the ensuing 48 hours. Sprint times declined further after 24 hours (1.85 ± 0.51) but were back to baseline at 48 hours.

**Effect of Recovery on Muscle Soreness**

Muscle soreness was effectively attenuated by both CWT and COLD (Table 1 and Figure 1). CWT reduced soreness

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**Table 1**  Muscle Soreness, Perceived Fatigue, Jump Performances, and Total Sprint Time (6 × 20-m) Before, Immediately After, and up to 48 Hours After Standardized Australian Football Training (N = 14, mean ± SD)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group</th>
<th>Pretraining</th>
<th>Posttraining</th>
<th>1 h</th>
<th>24 h</th>
<th>48 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle soreness</td>
<td>PAS</td>
<td>2.4 ± 0.9</td>
<td>4.9 ± 1.5d</td>
<td>5.4 ± 1.9d</td>
<td>7.9 ± 0.8d</td>
<td>6.4 ± 1.3d</td>
</tr>
<tr>
<td></td>
<td>COLD</td>
<td>2.8 ± 1.0</td>
<td>5.5 ± 0.9d</td>
<td>3.0 ± 1.2</td>
<td>3.4 ± 1.3a</td>
<td>2.8 ± 1.2</td>
</tr>
<tr>
<td></td>
<td>CWT</td>
<td>2.5 ± 1.4</td>
<td>4.5 ± 1.2c</td>
<td>3.2 ± 1.6a</td>
<td>4.3 ± 1.8b</td>
<td>3.5 ± 1.5b</td>
</tr>
<tr>
<td>Perceived fatigue</td>
<td>PAS</td>
<td>2.5 ± 0.7</td>
<td>6.1 ± 2.0d</td>
<td>5.7 ± 2.2d</td>
<td>4.7 ± 1.7d</td>
<td>4.9 ± 1.7d</td>
</tr>
<tr>
<td></td>
<td>COLD</td>
<td>2.6 ± 1.3</td>
<td>6.3 ± 0.9d</td>
<td>3.7 ± 1.2b</td>
<td>3.2 ± 1.3a</td>
<td>2.6 ± 1.3</td>
</tr>
<tr>
<td></td>
<td>CWT</td>
<td>2.3 ± 1.2</td>
<td>5.7 ± 1.1d</td>
<td>3.1 ± 1.1b</td>
<td>3.1 ± 1.3b</td>
<td>3.0 ± 1.4a</td>
</tr>
<tr>
<td>Countermovement jump*</td>
<td>PAS</td>
<td>0.67 ± 0.19</td>
<td>0.66 ± 0.17</td>
<td>—</td>
<td>0.66 ± 0.13</td>
<td>0.64 ± 0.18</td>
</tr>
<tr>
<td></td>
<td>COLD</td>
<td>0.69 ± 0.14</td>
<td>0.69 ± 0.11</td>
<td>—</td>
<td>0.68 ± 0.09</td>
<td>0.68 ± 0.12</td>
</tr>
<tr>
<td></td>
<td>CWT</td>
<td>0.68 ± 0.16</td>
<td>0.68 ± 0.13</td>
<td>—</td>
<td>0.67 ± 0.14</td>
<td>0.68 ± 0.15</td>
</tr>
<tr>
<td>Squat jump*</td>
<td>PAS</td>
<td>0.69 ± 0.17</td>
<td>0.67 ± 0.23</td>
<td>—</td>
<td>0.67 ± 0.17</td>
<td>0.67 ± 0.15</td>
</tr>
<tr>
<td></td>
<td>COLD</td>
<td>0.66 ± 0.14</td>
<td>0.62 ± 0.11</td>
<td>—</td>
<td>0.66 ± 0.09</td>
<td>0.67 ± 0.12</td>
</tr>
<tr>
<td></td>
<td>CWT</td>
<td>0.67 ± 0.17</td>
<td>0.63 ± 0.23</td>
<td>—</td>
<td>0.66 ± 0.17</td>
<td>0.66 ± 0.15</td>
</tr>
<tr>
<td>Total sprint time (s)</td>
<td>PAS</td>
<td>18.53 ± 0.38</td>
<td>18.97 ± 0.41b</td>
<td>—</td>
<td>18.28 ± 0.55c</td>
<td>18.62 ± 0.70</td>
</tr>
<tr>
<td></td>
<td>COLD</td>
<td>18.62 ± 0.46</td>
<td>19.01 ± 0.56b</td>
<td>—</td>
<td>18.62 ± 0.49</td>
<td>18.66 ± 0.46</td>
</tr>
<tr>
<td></td>
<td>CWT</td>
<td>18.63 ± 0.45</td>
<td>18.97 ± 0.46b</td>
<td>—</td>
<td>18.82 ± 0.51a</td>
<td>18.78 ± 0.53a</td>
</tr>
</tbody>
</table>

Abbreviations: PAS, passive recovery; COLD, cold-water immersion; CWT, contrast water therapy.

*a Small change (ES = 0.2–0.6); b moderate change (ES 0.6–1.2); c large change (ES 1.2–2.0); d very large change (ES >2.0). Effect-size data indicate difference compared with pretraining values.

*Ratio of flight time to contraction time (s).
at 1 (0.51 ± 0.57), 24 (1.25 ± 0.49), and 48 hours (0.69 ± 0.45), while COLD reduced soreness close to baseline at 1 hour, was effective at 24 hours (0.58 ± 0.53), and reduced soreness to pretraining levels after 48 hours.

COLD was the most effective modality at reducing training-induced soreness when evaluating its effectiveness against CWT and PAS (Table 2). Of the 2 water-based modalities, COLD was more effective than CWT at 24 (–0.95 ± 0.50) and 48 hours (–0.78 ± 0.47). Compared with PAS, CWT was better at alleviating muscle soreness at 1 (–1.60 ± 0.78), 24 (–2.58 ± 0.61), and 48 hours (–2.12 ± 0.63), and COLD was substantially lower at 1 (–1.99 ± 0.65), 24 (–3.53 ± 0.58), and 48 hours (–2.90 ± 0.54).

Effect of Recovery on Perceived Fatigue
Both CWT and COLD were effective at moderating perceived fatigue (Table 1 and Figure 1). Fatigue was attenuated by CWT at 1 (0.67 ± 0.38), 24 (0.63 ± 0.46), and 48 hours (0.56 ± 0.48). COLD also reduced fatigue after 1 (0.79 ± 0.38) and 24 hours (0.43 ± 0.48) while restoring fatigue to pretraining levels after 48 hours.

Compared with CWT and PAS, COLD was the most effective intervention at reducing perceptions of fatigue (Table 2). At 48 hours, COLD was more effective than CWT (–0.72 ± 0.46). Compared with PAS, both interventions were more successful at 1 (CWT –1.26 ± 0.46, COLD –1.28 ± 0.60), 24 (CWT –0.77 ± 0.58, COLD –0.99 ± 0.67), and 48 hours (CWT –0.91 ± 0.50, COLD –1.46 ± 0.52).

Effect of Recovery on Jump Performance
Comparisons for jump performances indicated no clear differences between groups (Table 1 and Figure 2). At 48 hours, countermovement jump was ameliorated effectively by CWT and COLD, while squat jump was improved above baseline slightly at 48 hours by COLD. Comparisons between interventions revealed COLD to be the most effective (Table 2).

Effect of Recovery on RSA
Both water recoveries were effective at attenuating RSA (Table 1 and Figure 2). Sprint times were attenuated by CWT at 24 (0.40 ± 0.29) and 48 hours (0.32 ± 0.25). For COLD, sprint time was restored back to baseline at 24 hours and near baseline after 48 hours.

Direct comparisons between interventions revealed COLD to be the most successful for restoring RSA at 24 hours, with PAS being the poorest (Table 2). COLD was more effective than CWT at both 24 (–0.37 ± 0.27) and 48 hours (–0.23 ± 0.22). In comparison with PAS, CWT (–1.29 ± 0.56) and COLD (–1.52 ± 0.40) were more effective after 24 hours, with no differences evident at 48 hours.

### Table 2 Change in Mean Between Treatment Groups for Muscle Soreness and Perceived Fatigue

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group</th>
<th>1 h</th>
<th>24 h</th>
<th>48 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle soreness</td>
<td>COLD vs PAS</td>
<td>↓ 2.8 ± 0.9c</td>
<td>↓ 4.9 ± 0.8d</td>
<td>↓ 4.0 ± 0.8d</td>
</tr>
<tr>
<td></td>
<td>CWT vs PAS</td>
<td>↓ 2.3 ± 1.0c</td>
<td>↓ 3.7 ± 0.9d</td>
<td>↓ 3.0 ± 0.9c</td>
</tr>
<tr>
<td></td>
<td>COLD vs CWT</td>
<td>↓ 0.5 ± 0.7</td>
<td>↓ 1.2 ± 0.6b</td>
<td>↓ 1.0 ± 0.6b</td>
</tr>
<tr>
<td>Perceived fatigue</td>
<td>COLD vs PAS</td>
<td>↓ 2.1 ± 1.0c</td>
<td>↓ 1.6 ± 1.1b</td>
<td>↓ 2.4 ± 0.8c</td>
</tr>
<tr>
<td></td>
<td>CWT vs PAS</td>
<td>↓ 2.4 ± 0.8c</td>
<td>↓ 1.4 ± 1.0b</td>
<td>↓ 1.7 ± 0.9b</td>
</tr>
<tr>
<td></td>
<td>COLD vs CWT</td>
<td>↑ 0.3 ± 0.7</td>
<td>↓ 0.2 ± 0.7</td>
<td>↑ 0.7 ± 0.5b</td>
</tr>
<tr>
<td>% change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Countermovement jump*</td>
<td>COLD vs PAS</td>
<td>—</td>
<td>↑ 0.3 ± 22.1</td>
<td>↑ 3.1 ± 29.2</td>
</tr>
<tr>
<td></td>
<td>CWT vs PAS</td>
<td>—</td>
<td>↓ 0.9 ± 22.5</td>
<td>↑ 3.1 ± 31.5</td>
</tr>
<tr>
<td></td>
<td>COLD vs CWT</td>
<td>—</td>
<td>↑ 1.2 ± 13.2</td>
<td>0.0 ± 12.8</td>
</tr>
<tr>
<td>Squat jump*</td>
<td>COLD vs PAS</td>
<td>—</td>
<td>↑ 4.3 ± 32.5</td>
<td>↑ 4.9 ± 18.8</td>
</tr>
<tr>
<td></td>
<td>CWT vs PAS</td>
<td>—</td>
<td>↑ 1.4 ± 17.8</td>
<td>↑ 0.7 ± 18.4</td>
</tr>
<tr>
<td></td>
<td>COLD vs CWT</td>
<td>—</td>
<td>↑ 2.9 ± 30.9</td>
<td>↑ 4.2 ± 20.4</td>
</tr>
<tr>
<td>Total sprint time (s)</td>
<td>COLD vs PAS</td>
<td>—</td>
<td>↓ 3.9 ± 1.1c</td>
<td>↓ 0.3 ± 1.3</td>
</tr>
<tr>
<td></td>
<td>CWT vs PAS</td>
<td>—</td>
<td>↓ 2.9 ± 1.3c</td>
<td>↑ 0.3 ± 1.3</td>
</tr>
<tr>
<td></td>
<td>COLD vs CWT</td>
<td>—</td>
<td>↓ 1.0 ± 0.7a</td>
<td>↓ 0.6 ± 0.4a</td>
</tr>
</tbody>
</table>

Abbreviations: PAS, passive recovery; COLD, cold-water immersion; CWT, contrast water therapy.

* Small change (ES = 0.2–0.6); b moderate change (ES 0.6–1.2); c large change (ES 1.2–2.0); d very large change (ES >2.0).

*Ratio of flight time to contraction time (s).
Figure 1 — Change in mean between interventions throughout the 48-hour recovery period for (A) muscle soreness and (B) perceived fatigue. * Small effect compared with pretraining; † Moderate effect compared with pretraining; ‡ Large effect compared with pretraining; ‡‡ Very large effect compared with pretraining; ‡‡‡ indicates moderate effect compared with cold-water immersion (COLD); ‡‡¶ indicates moderate difference compared with contrast water therapy (CWT); ‡‡‖ Large effect compared with COLD; ‡‡⊥ Large effect compared with CWT; ‡‡∥ Very large effect compared with COLD; ‡‡¶¶ Very large effect compared with CWT. Solid line with solid circle represents passive recovery. Dashed line with solid square represents COLD. Dotted line with solid triangle represents CWT.
Figure 2 — Percentage change between interventions throughout the 48-hour recovery period for (A) countermovement jump, (B) squat-jump performance, and (C) total sprint time (6 × 20-m sprints). * Small effect compared with pretraining; † Moderate effect compared with pretraining; ‡ Large effect compared with pretraining; § Small effect compared with cold-water immersion (COLD); ¶ Large effect compared with COLD; # Large effect compared with contrast water therapy (CWT). Solid line with solid circle represents passive recovery. Dashed line with solid square represents COLD. Dotted line with solid triangle represents CWT.
Discussion

The major finding of this investigation was that acute application of COLD was a more effective recovery method than CWT or PAS for restoring physical performance and psychometric perceptions after AF training. Furthermore, we established that AF training leads to functional and perceptual deficits that were prolonged for up to 48 hours. Finally, both COLD and CWT restored physical and perceptual measures during a typical AF training week. We also, for the first time in team sport, matched groups for time immersed in water.

Restoring and promoting performance should be the primary aim of any recovery session. We demonstrated that repeat-sprint performance declined substantially after training, and that after 24 hours, 14 minutes of either COLD or CWT were effective at ameliorating these declines, with COLD restoring sprint time back to baseline. This may allow AF players to be better prepared for any running and/or speed/agility work that typically occurs within 24 hours after a skills session during the preseason. The effectiveness of both interventions is in agreement with previous findings that COLD and CWT were effective at reducing declines in RSA in netballers.7 COLD also better maintained 20-m acceleration and sprint time after 3 days of basketball competition8 and enhanced 20-m-sprint and jumping performance after a soccer game.4

It is interesting that after 48 hours, COLD was more effective than CWT for restoring RSA, displaying similar results after simulated team-sport running.6 When compared with PAS at 48 hours, however, there were no clear differences for COLD or CWT. This is in contrast to results where COLD was more effective than PAS after simulated team-sport running.6 Differences may lie in the fact that after simulated running, athletes were subject to multiple COLD exposures (immediately and 24 h afterward) and not a single exposure, as was the case in this study, or that simulated running resulted in greater muscle damage experienced by athletes.

Training induced a pronounced increase in postexercise muscle soreness, which persisted during the 48-hour recovery period for the PAS group. This is consistent with previous research and indicates that the acute effects of exercise can persist throughout the ensuing recovery period.1,4,6,8,10,11 Both COLD and CWT had a marked positive effect on alleviating postexercise muscle soreness, with COLD fully restoring soreness to preexercise levels. Delayed-onset muscle soreness can lead to increased injury risk,2 and with COLD and CWT reducing soreness effectively, postraining recovery may have an important role in preventing injury.

Similar to soreness, the perception of fatigue rose markedly postraining. Both COLD and CWT were effective at diminishing fatigue postraining, with COLD returning it to preexercise values. This concurs with earlier research. Previously, COLD moderated fatigue between successive soccer matches9 and attenuated cumulative fatigue over a 3-day basketball tournament,8 while COLD and CWT reduced fatigue over 5 days of cycling.1

After a game of AF, the ratio of countermovement-jump flight time to contraction time has been established as the most sensitive and useful variable to assess neuromuscular fatigue.24 However, the results in this study suggest that jump performance may not be the best indicator of fatigue after training, so it may not be an appropriate postraining measure. AF training contains less high-intensity movement and physical pressure than games do,28 so it should fail to elicit the fatigue and subsequent reductions in jump performance reported after games.24 It has also been suggested that even when sore, players may still be able to produce one-off efforts equal or close to their best, and that repeat-effort tests may be a better way to assess functional decrements.5 This may have been the case with the PAS group.

The effectiveness of CWT and COLD over PAS may be explained by the physiological effects of hydrostatic pressure. Due to increased fluid shifts from the extremities to the central cavity, hydrostatic pressure can help restrict edema accumulation in muscle postexercise.18 This can help decrease inflammation, which can alter force-generating capacity29 and subsequent performance.18 Being submerged can also induce a feeling of weightlessness, which can provide greater relaxation and help reduce perceptions of fatigue.18

The physiological effects of temperature may also explain the effectiveness of COLD and CWT. Cold is often used in the treatment of inflammation to improve the rehabilitation process and has a number of other effects including analgesia, localized vasoconstriction, decreased rate of muscle metabolism, reduced fluid diffusion and vascular permeability, reduced edema formation, and decreased acute inflammation responses to muscle damage.15–17 These effects can help reduce the loss of force generation, pain, and swelling that are often associated with inflammation29 and attenuate any physical-performance decrease.18 In contrast, superficial heat can increase the inflammatory response and edema, so heat application during CWT may be detrimental to athletes.16,18 Although this may be counteracted by the subsequent application of cold, the overall decrease in inflammation and edema may not be as great as 14 continuous minutes of cold. This may then diminish CWT’s effectiveness at reducing pain and swelling. Consequently, the effects of increased exposure to cold combined with continuous hydrostatic pressure may explain why COLD was more effective than CWT throughout this investigation.

We acknowledge that this study had some limitations. The first was that due to continued construction of facilities and therefore limited access, all players were forced to perform the PAS protocol during week 1. Although this was the case, all players at the time of testing were familiar with the training and the small-sided games that were used. Players had also partaken in this type of training on numerous occasions during the 16 to 17 previous weeks of preseason. Due to the nature
of water immersion, it was not possible to incorporate a placebo control for each of the water conditions and immersion durations, so we cannot dismiss a treatment effect. In sedentary subjects, regular use of COLD interventions blunted some training adaptations over a 4- to 6-week period. Subjects performed multiple 20-minute COLD immersions at 5°C, and although not fully representative of protocols and temperatures used by athletic populations, this result may be of some concern. As this investigation was concerned with the acute single application of COLD or CWT, we are not able to determine any long-term impairments, but we believe that further investigation regarding this possibility is warranted. Endurance fitness remains important for elite AF players, but we were unable to measure the effects of COLD and CWT on this. As we were committed to using professional athletes, constraints placed on us meant that we were unable to include endurance testing, which would have caused too much disruption to the training and upcoming game schedule.

Practical Applications

Players, coaches, and sport science and medical staff should be aware that AF training leads to reductions in physical and psychometric measures over a 24- to 48-hour period and that the use of COLD or CWT can attenuate posttraining physical and psychometric reductions. Staff and athletes also need to be aware that after AF training, COLD is more effective than CWT or PAS in restoring RSA, as well as reducing perceptions of soreness and fatigue. Further research is needed to determine the effects of a single application of COLD and/or CWT after a game of AF.

Conclusion

Improving physical performance may be important during an AF season. Players are generally expected to train 24 to 72 hours after their previous session, while during the preseason they are generally expected to train within 24 hours. Therefore, attenuating the decline in physical performance between sessions is critical to these athletes. The unique nature of this study effectively demonstrated that 14 minutes of either COLD or CWT can help athletes recover from typical AF training conditions. Through this study, an acute application of COLD was established as the superior modality for AF players after a training session. It clearly outperformed both CWT and PAS in minimizing muscle soreness and perceived fatigue, as well as helping to more rapidly restore repeat-sprint performance.

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References


