Effect of Contrast Water Therapy Duration on Recovery of Running Performance

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Purpose: To investigate whether contrast water therapy (CWT) assists acute recovery from high-intensity running and whether a dose-response relationship exists. Methods: Ten trained male runners completed 4 trials, each commencing with a 3000-m time trial, followed by 8 × 400-m intervals with 1 min of recovery. Ten minutes postexercise, participants performed 1 of 4 recovery protocols: CWT, by alternating 1 min hot (38°C) and 1 min cold (15°C) for 6 (CWT6), 12 (CWT12), or 18 min (CWT18), or a seated rest control trial. The 3000-m time trial was repeated 2 h later. Results: 3000-m performance slowed from 632 ± 4 to 647 ± 4 s in control, 631 ± 4 to 642 ± 4 s in CWT6, 633 ± 4 to 648 ± 4 s in CWT12, and 631 ± 4 to 647 ± 4 s in CWT18. Following CWT6, performance (smallest worthwhile change of 0.3%) was substantially faster than control (87% probability, 0.8 ± 0.8% mean ± 90% confidence limit), however, there was no effect for CWT12 (34%, 0.0 ± 1.0%) or CWT18 (34%, –0.1 ± 0.8%). There were no substantial differences between conditions in exercise heart rates, or postexercise calf and thigh girths. Algometer thigh pain threshold during CWT12 was higher at all time points compared with control. Subjective measures of thermal sensation and muscle soreness were lower in all CWT conditions at some post-water-immersion time points compared with control; however, there were no consistent differences in whole body fatigue following CWT. Conclusions: Contrast water therapy for 6 min assisted acute recovery from high-intensity running; however, CWT duration did not have a dose-response effect on recovery of running performance.

Keywords: exercise, hydrotherapy, fatigue, dose response, time trial

Elite middle and long-distance runners may regularly become fatigued, as they typically train one or more times per day, for 6–7 d/wk and may also compete on consecutive days, often at very high intensities. In addition, many individual (triathlon) and team sports (football, hockey) involve large amounts of running, often at high intensities,1–3 also resulting in fatigue. To maximize exercise performance in the short term (the subsequent training session, or competition heat/round), athletes must recover as fast as possible.

Contrast water therapy (CWT) is increasingly being used by runners and other athletes to accelerate postexercise recovery, with athletes alternating several times between hot and cold water immersion (1–2 min in each). Conflicting literature exists on the ability of CWT to assist acute postexercise recovery. A number of studies have reported beneficial effects on performance;5–10 however, others have found no change.4,11–15 While it has been suggested that the lack of an effect on performance could be partly due to the methodology used,16 it may alternatively be due to a lack of change in intramuscular temperature.16,17 In addition, it has been suggested that accelerating acute recovery by disrupting the mechanisms of fatigue may blunt adaptations to training, potentially inhibiting long-term improvements in fitness.18–20 The effect of CWT on long-term adaptations to training warrants further investigation; however, this is beyond the scope of the present study. The range of CWT protocols, and potential mechanisms by which they might affect recovery from exercise have been discussed in recent review articles.21,22

To our knowledge, only Coffey et al11 have investigated whether CWT could accelerate recovery from high-intensity running (time to exhaustion at 120 and 90% of peak running speed). They found that 15 min of CWT, active recovery or passive standing recovery had no effect on subsequent treadmill running performance 4 h later. It was suggested that the 4 h between exercise bouts was sufficient time to allow athletes to recover fully, overriding any acute effects of the CWT or active recovery interventions. To our knowledge, no other papers have examined the acute effect of CWT on subsequent high-intensity running performance.

Recovery from team sport exercise demands after using CWT has been assessed by measuring running repeat sprint ability. Hamlin et al.,13,14 Ingram et al.,4 and King et al.23 all reported that CWT had no effect on
recovery of performance compared with active recovery or control conditions, possibly because the body was immersed only to waist level in cold water, and hot showers were used instead of water immersion.

To our knowledge, previous work from our laboratory is the only attempt to determine the ideal duration of CWT. We compared the effect of performing postexercise CWT (alternating 1 min hot, and 1 min cold) for 6, 12, or 18 min on high-intensity cycling performance 90 min later. It was found that 6 min of CWT improved time-trial and sprint performance, whereas 12 min only improved sprint performance. Therefore, a dose-response relationship was not found between CWT duration and subsequent high-intensity cycling performance.

The present study was designed to replicate our previous investigation, using high-intensity running instead of cycling. Running involves eccentric muscle contractions, which can cause significant muscle damage. In contrast, less muscle damage is generally evident after predominantly concentric exercise such as cycling, thus allowing any effect of CWT on recovery from different modes of exercise to be compared. The primary purpose of this study was to determine if CWT assists acute, same-day recovery from high-intensity running performance. In addition, the study aimed to determine if a dose-response relationship exists between CWT duration and subsequent high-intensity running performance. It was hypothesized that CWT would assist acute, same-day postexercise recovery, therefore improving subsequent high-intensity running performance, and that performing CWT for a longer duration would increase recovery benefits, as running generally promotes more muscle damage than cycling.

Methods

Subjects

Ten trained male long-distance runners (mean ± SD, age: 36.8 ± 9.2 y, height: 1.79 ± 0.08 m, body mass: 70.8 ± 8.3 kg, VO2max: 64.3 ± 5.0 mL · kg⁻¹ · min⁻¹, sum of seven skinfolds: 49.3 ± 12.0 mm) volunteered for the study. The participants typically covered >60 km/wk in training, and were not regular users of hydrotherapy recovery techniques. Participants were informed of the risks and provided written informed consent. The study was approved by the Australian Institute of Sport (AIS) Research Ethics Committee in the spirit of the Helsinki Declaration, and conducted according to the protocols recommended by Harris and Atkinson.

Experimental Design

This study used a study design, interventions, and outcome measures similar to that of Versey et al, except participants performed high-intensity running instead of cycling. The study used a post-only crossover design with time trial 1 and wind speed as covariates. Participants completed 2 familiarizations to minimize any learning or training effects, followed by 4 trials in randomized, counterbalanced order separated by a minimum of 4 d. Trials differed only in the recovery protocol and each participant performed their trials at the same time of day.

Procedures

Before the study, participants performed a VO2max test on a custom-built motorized treadmill (AIS, Canberra, Australia) as described in Robertson et al, with running speeds adjusted to suit the participants (submaximal speed range: 13–17 km/h). A participant’s sum of 7 skinfolds was measured by a certified ISAK level 2 anthropometrist.

During the 24 h before each trial, participants repeated the same training consisting of up to 45 min of low-intensity exercise to ensure they commenced each trial with a similar (low) level of fatigue. Participants also completed a food diary to ensure energy and fluid consumptions were similar on each occasion, and did not consume caffeine or alcohol during the 24 h before each trial. At 90 min before each trial, participants consumed standardized food (2 g of carbohydrate per kilogram of body mass) and fluid (850 mL) to limit substrate depletion and dehydration as sources of fatigue.

Each trial (Figure 1) commenced with exercise bout 1 (Ex 1), whereby participants initially performed a 15-min self-paced warm-up, including 3 × 100 m efforts at predicted 3000-m time-trial pace. They then completed a maximal 3000-m running time trial (time trial 1) on an International Association of Athletics Federations standard 400-m athletics track (AIS, Canberra, Australia) to measure performance. Five minutes later, participants commenced a set of 8 × 400 m intervals, with 1 min of recovery between efforts, aiming to complete the intervals in the fastest cumulative time possible. This is a typical training set performed by middle and long-distance runners and was designed to increase fatigue levels. A 7-min self-paced warm-down was then performed in all conditions. Two hours after completing Ex 1, the warm-up, 3000-m time trial (time trial 2), and warm-down were repeated in exercise bout 2 (Ex 2) to determine the affect of the recovery interventions on performance. The 2 h break was designed to be short enough to ensure a decrease in performance in the control trial, while simulating the twice a day training frequently performed by middle and long-distance runners. At 90 min before Ex 2, participants again consumed the standardized food and fluid intake.

To avoid pacing, participants did not receive their splits, final times, or heart rate data until after each trial. In addition, participants’ start times were separated by 10 s to decrease the likelihood of pacing off other runners. The same researcher conducted all trials and provided strong, consistent verbal encouragement throughout. To minimize the effect of environmental conditions (temperature: 14.9 ± 4.9°C, humidity: 50 ± 16%, wind speed: 0.4 ± 0.8 m/s) on performance, trials were rescheduled when hot or windy conditions were predicted. Despite this, unexpected low wind speeds were present in some
Trials. Trials were performed in winter and spring, resulting in a relatively large standard deviation in air temperature and ad libitum water consumption (571 ± 477 mL) during each trial.

Recovery Interventions

Ten minutes after Ex 1, participants performed 1 of 4 recovery protocols: CWT for 6 (CWT6), 12 (CWT12), or 18 (CWT18) min in duration, or a seated rest control trial (temperature: 21.7 ± 2.7°C, humidity: 43.0 ± 9.3%). The CWT alternated between hot (38.4 ± 0.3°C) and cold water (14.6 ± 0.5°C) (T106 thermometer, Testo AG, Germany) every minute with a 5-s changeover. Participants immersed their entire body (seated, excluding head and neck) in the pools. The CWT protocol was based on previous research that found it to be effective at accelerating recovery of exercise performance.6,9,10,20 In addition, it maximized movement between extreme temperatures and involved equal durations of hot and cold water immersion. Following CWT, participants sat at rest (temperature: 22.1 ± 2.4°C, humidity: 41.0 ± 7.4%) until Ex 2 and did not perform any additional organized recovery strategies, including stretching, massage, napping, or compression garments.

Recovery Assessment

Running Performance. Running performances in the 3000-m time trial 2 were the primary measure of recovery. Split and final times were measured using a stopwatch (S141, Seiko, Japan). Times for each of the 400-m intervals were added to provide a total time. The typical errors were 1.1 and 1.2% for the time trial and interval total times, respectively.

Heart Rate. Heart rate was logged every 5 s by a Polar heart rate monitor (S810i, Polar, Finland). Average heart rate for each time trial and peak heart rate at the end of the interval set were determined.

Leg Girths. Calf and mid-thigh girths were measured on the right leg according to the International Standards for Anthropometric Assessment28 as an indicator of leg edema. The positions of the tape (W606PM, Lufkin, USA) were marked on the leg to ensure the same locations were measured throughout each trial, therefore improving reliability. Typical errors for calf and thigh girth were each 0.1%. Calf and thigh girths were measured pre Ex 1, immediately, 30, 60, and 90 min after Ex 1, and immediately after Ex 2.

Algometer Measures. Pressure-to-pain threshold was measured as an indicator of quadriceps muscle soreness at the front-thigh skinfold site with the participant supine, and calf muscle soreness at the height of the medial-calf skinfold site 3 cm lateral to the midline of the calf with the participant prone.28 Both measures were made on the right leg using a calibrated algometer (Somedic, Sweden) according to the manufacturer’s instructions. A flat, circular probe with a surface area of 2 cm² and covered with a 2-mm-thick piece of rubber was pressed perpendicularly against the skin. A single operator aimed to maintain a rate of increase in pressure at 30 kPa/s, and feedback on the rate of increase was provided by the

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Figure 1 — Schematic of conditions indicating when exercise bouts 1 (Ex 1) and 2 (Ex 2); contrast water therapy of 6 (CWT6), 12 (CWT12), or 18 (CWT18) min in duration; and seated rest occurred. *Indicates standardized food and fluid consumption.
digital display on the algometer. However, the operator was blinded to the absolute pressure value until the participants had pressed a switch when their sensation changed from pressure to pain. Measures were made in duplicate 10 s apart, with typical errors for calf and thigh pressure-to-pain threshold of 6.5 and 9.7% respectively. Pressure-to-pain threshold differed between duplicate measures for the calf and thigh by 1.0 \( (P = .485) \) and \(-2.3\% (P = .272) \) respectively. Algometer measures were made before Ex 1; immediately, 30, 60, and 90 min after Ex 1; and immediately after Ex 2.

**Subjective Measures.** Rating of perceived exertion (RPE), effort, and motivation were recorded after each time trial. The RPE was on a scale of 6 (no exertion) to 20 (maximal exertion); effort and motivation were rated 3000-m running races and be similar to other middle and long-distance events. Hopkins et al\textsuperscript{34} calculated the smallest worthwhile change that could influence performance in a competitive event as 0.3 times the within-athlete smallest worthwhile change from the following comparisons was calculated: Control versus CWT6, CWT6 versus CWT12, and CWT12 versus CWT18.

### Results

#### Running Performance

Smallest worthwhile change in 3000-m time-trial performance was calculated as 0.3%. Descriptive statistics for 3000-m time trials and the 400-m interval set are shown in Table 1. Performance in time trial 1 and the interval set did not differ between conditions and slowed from time trial 1 to 2 in all conditions. Time-trial 2 performance for each condition (compared with control) are shown in Figure 2, performance following CWT6 was substantially faster than control (87% probability, 0.8 ± 0.8% mean ± 90% CL); however, CWT12 (34%, 0.0 ± 1.0%) and CWT18 (34%, −0.1 ± 0.8%) had no effect.

#### Heart Rate

Descriptive heart rate data are shown in Table 1. No substantial differences existed between conditions in time-trial average heart rate during Ex 1 or Ex 2, or in interval peak heart rate. All effects were trivial or unclear with an effect size <0.20.

#### Leg Girths

Calf and thigh girths for each condition (compared with control) are shown in Figure 3. No substantial differences between conditions were found at any time point, with all effects being trivial (effect size <0.20).

#### Algometer Measures

Calf and thigh pressure to pain thresholds for each condition (compared with control) are shown in Figure 4 (larger values represent a higher pain threshold), data for CWT6 and CWT18 are based on nine participants. Thigh pressure-to-pain threshold was higher in CWT12 compared with control at all time points.

#### Subjective Measures

The RPE was not substantially different between conditions after time trial 1. After time trial 2, RPE was substantially lower following CWT6 (75%, −0.41 ± 0.54)
Table 1  Descriptive Statistics (Mean ± Percent Coefficient of Variation) for Performance and Heart Rate Data in Control, CWT6, CWT12, and CWT18 Conditions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>CWT6</th>
<th>CWT12</th>
<th>CWT18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000-m time trial 1</td>
<td>632 ± 4a</td>
<td>631 ± 4a</td>
<td>633 ± 4a</td>
<td>631 ± 4a</td>
</tr>
<tr>
<td>400-m intervals (total time)</td>
<td>617 ± 4</td>
<td>615 ± 4</td>
<td>620 ± 4</td>
<td>622 ± 4</td>
</tr>
<tr>
<td>3000-m time trial 2</td>
<td>647 ± 4</td>
<td>642 ± 4b</td>
<td>648 ± 4</td>
<td>647 ± 4</td>
</tr>
<tr>
<td>Heart Rate (bpm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000-m time trial 1 (average)</td>
<td>165 ± 5</td>
<td>166 ± 5</td>
<td>166 ± 5</td>
<td>166 ± 5</td>
</tr>
<tr>
<td>400-m intervals (peak)</td>
<td>171 ± 4</td>
<td>171 ± 4</td>
<td>171 ± 4</td>
<td>170 ± 4</td>
</tr>
<tr>
<td>3000-m time trial 2 (average)</td>
<td>166 ± 5</td>
<td>167 ± 5</td>
<td>166 ± 5</td>
<td>166 ± 5</td>
</tr>
</tbody>
</table>

Abbreviations: bpm = beats per minute.
Contrast water therapy for 6 (CWT6), 12 (CWT12), or 18 (CWT18) min in duration.
a Substantial difference between time trial 1 and 2 within a condition.
b Substantial difference in time trial 2 compared with control.

The present study investigated whether postexercise CWT assisted subsequent high-intensity running performance 2 h later, and if a dose-response relationship existed. The main findings were that recovery of 3000-m running time-trial performance was substantially faster following 6 min of CWT compared with no intervention, and that 12 and 18 min of CWT did not accelerate recovery of performance (Figure 2). As a result, CWT duration did not have a dose-response effect on acute recovery of high-intensity running performance.

Coffey et al11 investigated whether CWT accelerates recovery from high-intensity running performance, they performed two pairs of treadmill time-to-exhaustion tests at 120 and 90% of peak running speed, with 4 h between each pair of tests. Following the first pair of tests participants performed 15 min of CWT (alternating 60 s in 10°C, and 120 s in 42°C water), active recovery (running at 40% of peak running speed) or passive standing recovery. They found that CWT did not have an effect on subsequent treadmill running performance compared with the active and passive recovery conditions; however, they suggested that...
was sufficient time to allow participants to recover fully in all conditions, overriding any acute effects of the CWT recovery intervention. The present study also used a strenuous exercise protocol, but a shorter (2 h) break between exercise bouts. A decrease in 3000-m running performance (~2.4%) was observed from time trial 1 to 2 in the control condition, and a reduced magnitude of decline in performance was observed following CWT6.

The effect of CWT on recovery of team sport demands has been assessed in a number of studies by measuring running repeat sprint ability. Hamlin et al examined the acute affect of performing postexercise CWT for 6 min (alternating 1 min in 8–10°C water, and 1 min in a 38°C shower) on repeat sprint tests (10 × 40 m sprints on 30 s) separated by 60 min in developmental-level rugby players, and repeat sprint tests (6 × 5, 10 and 15 m shuttles on 30 s) separated by 2 h in developmental-level netballers. In contrast to the findings of the present study, these studies reported that 6 min of CWT did not affect subsequent repeat sprint test performance. The contrasting findings could be due to the different exercise protocols, as repeat sprint test performance requires different energy system contributions to middle-distance running, or the different CWT protocols performed in the respective studies. In the present study, participants performed full body water immersion; however, Hamlin et al immersed participants only to hip level in cold water and used hot showers on the legs. Full body immersion will likely produce a greater physiological response than half body immersion or showers due to the greater proportion of the body in contact with water, and the effects of hydrostatic pressure on the body.

Figure 3 — Calf (a) and thigh girth (b) for contrast water therapy of 6 (CWT6), 12 (CWT12), and 18 (CWT18) min in duration compared with control (dotted line). Data are the mean ± 90% CL. Ex 1 = Exercise bout 1, Ex 2 = Exercise bout 2. Shaded boxes indicate the CWT durations. There were no substantial differences between conditions.
The present study replicated previous work from our laboratory; however, participants performed high-intensity running instead of cycling. We previously reported that CWT6 improved 5-min cycling time-trial performance by 1.5 ± 2.1% compared with control, whereas CWT12 and CWT18 had no effect. The decrease in cycling time-trial average power in the control trial (1.8%) was comparable to the increase in running time-trial duration in the present study (2.4%). Cycling sprint total work was also greater after CWT6 (3.0 ± 3.1%) and CWT12 (4.3 ± 3.4%) compared with control. Comparing these results to the running time trials performed in the present study suggests that CWT6 is the duration most likely to assist recovery of performance and that high-intensity cycling is likely to benefit by a greater magnitude than running (0.8 ± 0.8%) within a 2-h time frame. We hypothesized that CWT of greater durations would assist recovery from running more than cycling, due to the greater muscle damage generally caused by the eccentric muscle contractions involved in running, compared with the predominantly concentric contractions in cycling.

The results of this and our previous study both suggest that postexercise CWT18 was too long to assist exercise performance 2 h later, and therefore a dose-response relationship does not exist between CWT duration and subsequent high-intensity running or cycling performance. We had anticipated that all CWT conditions would assist recovery of exercise performance and that a dose-response relationship might exist. In the present

![Figure 4](image-url)

**Figure 4** — Calf (a) and thigh pressure-to-pain threshold (b) for contrast water therapy of 6 (CWT6) (n = 9), 12 (CWT12), and 18 (CWT18) (n = 9) min in duration compared with control (dotted line). Data are means ± 90% CL. Ex 1 = Exercise bout 1, Ex 2 = Exercise bout 2. Shaded boxes indicate the CWT durations. Substantial effects for CWT trials compared with control are indicated by 12 or 18.
Figure 5 — Thermal sensation (a), whole body fatigue (b), and muscle soreness (c) for contrast water therapy of 6 (CWT6), 12 (CWT12), and 18 (CWT18) min in duration compared with control (dotted line). Data are means ± 90% CL. Ex 1 = Exercise bout 1, Ex 2 = Exercise bout 2. Shaded boxes indicate the CWT durations. Substantial effects for CWT trials compared with control are indicated by 6, 12, or 18.
study, CWT12 and CW18 did not assist recovery of running performance, possibly because their cooling effects were too large for the cold environmental conditions (14.9 ± 4.9°C) experienced by participants during exercise, potentially hindering their ability to warm up in Ex 2. Participants generally reported lower thermal sensations following all CWT immersions until Ex 2 compared with control. Following Ex 2 thermal sensation was still lower in CWT18 (Figure 5). An elevation in internal body temperatures is recognized as an important component of warming up for exercise and the subsequent improvement in performance.38

Our previous investigation10 also found that core temperatures before Ex 2 were substantially lower following CWT12 (–0.19 ± 0.14°C) and CWT18 (–0.21 ± 0.10°C) compared with control. Core temperature was not measured in the present study because it was not practical or comfortable for rectal temperature to be recorded while running in the field. Participants here probably experienced changes in core temperature similar to those of our previous investigation10 because the same CWT protocols were performed; however, due to the colder outdoor environmental conditions, this may have occurred at a lower absolute core temperature. If this study was repeated in warmer environmental conditions, CWT12 and CWT18 might also assist in the recovery of running performance. It should be noted that Vaile et al6 reported no difference in core temperature values between control and CWT (alternating 1 min in 38°C, and 1 min in 15°C water for 14 min) in the 15 min following CWT, but the reason for these differing findings is unclear.

Previous studies reporting that CWT assists postexercise recovery have used immersion durations of 14,6,9 and 15 min,3 and measured performance for up to 4 d postexercise. Other studies have performed CWT for shorter durations, but as discussed previously, 2 used hot showers instead of pools, and failed to use full body immersion,13,14 potentially decreasing any beneficial effects of CWT, while the third did not have a control condition.12 The combined results of the present study and the previously discussed literature, suggests that full body CWT immersion durations of 6–15 min are most appropriate for assisting postexercise recovery of performance.

Heart rate, leg girths, and pressure-to-pain thresholds were measured here to help explain changes in exercise performance. Heart rate did not differ between conditions at any time point (Table 1), indicating the improved performance in CWT6 was not due to participants sustaining a higher heart rate during exercise. Likewise, there were no differences between conditions in leg girths at any time point (Figure 3), suggesting that CWT did not alter calf or thigh swelling in response to fatiguing exercise. In contrast, Vaile et al3 reported a decreased thigh volume immediately and 48 h following eccentric leg-press exercise and CWT. However, the contrasting findings could be because the leg-press protocol was specifically designed to induce muscle damage and delayed onset muscle soreness, possibly causing greater fluid shifts and inflammation than the running protocol in the present study.

Calf and thigh pressure-to-pain thresholds were no different in CWT6 compared with control (Figure 4); therefore, the faster time-trial performance in CWT6 was probably not due to an increased pressure-to-pain threshold. In addition, the increased thigh pressure-to-pain threshold following CWT12 did not appear to improve subsequent running performance. The mechanisms by which CWT affects postexercise recovery are unclear and warrant further investigation to optimize CWT protocols for athletes.

Three of 7 participants selected CWT6 as the recovery condition they were most likely to use in a competitive situation, despite CWT6 resulting in the greatest performance recovery. The authors believe this was largely because 3 other participants selected CWT18 based on the theory of “more is better.” The participants were asked to provide these rankings based on their experiences during the study; however, their existing beliefs are likely to have influenced their responses. The participants existing beliefs could also explain why 6 of 7 participants would prefer to use CWT of any duration over no intervention.

The possibility of a placebo effect in the present study is acknowledged. However, in studies of this type, it is virtually impossible to blind the participants and researchers to the water temperatures and immersion durations. Effort and motivation during the 3000-m time trials were measured, as they are factors that can influence exercise performance. However, here the participants reported few differences in effort and motivation between conditions; therefore, any differences in performance are unlikely to be due to these factors.

**Practical Applications and Conclusions**

The findings of the present study suggest that performing postexercise CWT for 6 min might accelerate subsequent 3000-m time-trial running performance 2 h later; however, a dose-response relationship does not exist between CWT duration and recovery of running performance. Performing CWT for 12 and 18 min did not accelerate recovery when exercising outdoors in cold environmental conditions. The effect of performing CWT on subsequent high-intensity running performance in warmer environmental conditions is unknown and requires further investigation.

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References


