



Original article

Comparison of different cryotherapy recovery methods in elite junior cyclists

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Abstract

Background/objective: Cold water immersion (CWI) and active recovery treatment (ACT) are commonly used recovery treatments for athletes between exercise bouts, but they are sometimes limited by space and availability of equipment in training and competition venues. Therefore, the purpose of this study was to determine whether cold compression therapy (CCT) would provide the same effect as CWI and ACT as an alternative option in a hot environment.

Methods: Eight elite male junior cyclists (age, 15.5 ± 1.2 years; height, 167.7 ± 3.3 cm; body mass, 57.3 ± 3.5 kg; peak oxygen uptake, 64.7 ± 4.3 mL/kg/min) completed a maximal cycling test to determine their peak power output (PPO) and oxygen uptake. Then they completed three tests using randomised recovery protocol of CWI, CCT and ACT for 15 minutes. Each test consisted of two 35-minute exercise bouts, with 5 minutes of warm-up, 15 minutes of cycling at 75% PPO and 15 minutes maximal trial. The two exercise bouts were separated by 60 minutes (5 minutes cool-down, 10 minutes preparation for recovery treatment, 15 minutes recovery treatment, and 30 minutes passive recovery).

Results: There was no significant difference between average power output, blood lactate, rating of perceived exertion, and heart rate for two time-trial bouts for all recovery treatments. A significant decrease in core temperature was noted prior to the start of the second exercise bout for CWI.

Conclusion: CCT, CWI and ACT are all useful recovery treatments between exercise bouts.

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Keywords: cryotherapy; immersion; intermittent pneumatic compression device

Introduction

Various postexercise strategies were developed in an effort to boost recovery effect during training and competition in the past decade. Among these strategies, cryotherapy—originally used to prevent swelling of acute musculoskeletal injuries^{1–3}—is a common recovery method used after elite sporting events, especially for those who have a training and competition schedule that requires several bouts of exercises within 1 day or under environments of extreme heat and humidity. During training or competition in a hot environment,

an increased ambient temperature may reduce the contractibility of muscle and central motor drive, and thus decrease overall muscle performance and may lead to heat injury.^{4–6}

It is crucial to adopt suitable recovery modalities during the postexercise period as it would affect the training effect afterwards. Specifically, the majority of research has indicated that cold water immersion (CWI) is a common method to induce vasoconstriction, stimulating venous return, aiding metabolite removal after exercise, and reducing swelling and muscle soreness for better recovery during multiple exercise bouts.^{7–9} However, factors such as water temperature and duration of immersion can be manipulated to influence the thermal outcome. For example, Peiffer et al¹⁰ compared three different cold-water (14°C) immersion durations (5 minutes, 10 minutes, and 20 minutes) on both rectal and muscle

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temperature following a time-to-exhaustion cycling trial in a hot environment. Their result showed that 5 minutes of CWI did not decrease the muscle temperature after cooling, whereas there was no significant difference between 10 minutes and 20 minutes of treatment. Moreover, Vaile et al.⁸ compared the mean body temperature after 15 minutes of CWI protocols at different temperatures (10°C, 15°C and 20°C), and suggested that athletes performed better after CWI at 15°C was applied for recovery in an endurance event.

Although CWI is becoming increasingly popular to enhance recovery from training and competition, uniform and equipment constraints may hinder its usage, especially during races.¹¹ For road cycling events with short resting duration, CWI may not be preferred for cyclists as the resting locations are not always the same, and it is not practical to set up a movable immersion pool. In addition, the true effect on anaerobic performance is still under debate. Crowe et al.¹² examined the effect of 15-minute CWI in between two bouts of 30-second all-out cycling tests. Although the blood lactate level after CWI was significantly reduced when compared to that of the passive rest group, peak power and total work were significantly lower than the latter, which suggested that CWI is not a preferable recovery method to passive recovery in terms of anaerobic performance.

In contrast, cold compression therapy (CCT) can be achieved by applying cold compression wrap on local injury or worked-out sites. It shares the same principle of reducing muscle tissue temperature with CWI without the associated inconveniences of CWI. CCT may be as effective as CWI and has been used as an alternative recovery technique for multiple exercise bouts within the same day.^{11,13} However, little scientific evidence exists to substantiate its effectiveness on postexercise recovery.

To the authors' knowledge, there was only one study that reported ice application with adjunctive compression leading to a greater magnitude and rate of cooling when compared with the ice application without compression. Janwantanakul¹⁴ examined the effect of different levels of compression in ice treatment and found that with a higher level of compression, a shorter time was required to lower the temperature. This justified the use of compression wrap during rehabilitation and after exercise for higher recovery rate. Meanwhile, compression has been proven to be effective in preventing performance degradation as well as muscle soreness.¹⁵ An increase in hydrostatic pressure on the body may have contributed to the beneficial effect of lower rectal temperature during CWI. De Pauw et al.¹⁶ examined the effects of cooling with compression for recovery between two same-day bouts of 30-minute cycling time trials and found no significant differences in performance when compared with passive recovery. This may be attributable to the small surface area covered by the cooling apparatus and the fairly low pressure applied (20 mmHg). Moreover, there was no comparison between CCT and CWI strategy in any form of indicators in exercise performance in the study.¹⁶

Active recovery treatment (ACT), which refers to gentle exercise during the recovery period, has been widely adopted

by athletes between two exercise bouts. ACT was proven to enhance lactate removal and improve sports performance.¹⁶ Therefore, ACT serves as an ideal control for investigating the effect of different recovery treatments. However, ACT may not be allowed in some training and competition venues because of limited space and equipment.

Developing experimental models to examine the value of recovery modalities as integral components of training specific to the needs of athletes should consider exercise mode, training volume, and intensity.¹⁷ Most studies of CWI treatment in cycling that lasted for 5–30 minutes did not provide clear and specific guidelines for cryotherapy.^{13,18,19} Post-treatment recovery time ranged from 30 minutes to 48 hours.^{8,9,15} For sports with multiple bouts and short rest intervals in between, for example, track cycling, a plausible and realistic recovery modality should be well defined. As aforementioned, CCT could be a substitute for CWI as they have a similar recovery effect, and CCT also has a more convenient setup. Therefore, the purpose of the present study was to determine whether CCT intervention would provide the same effect as CWI and ACT treatment on recovery in a hot environment. It was hypothesised that CWI, ACT, and CCT should have no significant differences in recovery effect by comparing cycling performance after a rest interval in between sessions.

Materials and methods

Eight elite male junior cyclists (mean \pm standard deviation; age, 15.5 ± 1.2 years; height, 167.7 ± 3.3 cm; body mass, 57.3 ± 3.5 kg; peak oxygen uptake, 64.7 ± 4.3 mL/kg/min) were recruited to participate in this study. All participants provided written informed consent and were free from any known illness and cardiovascular concerns at the start of the study. The experimental procedures and risk factors were explained to all participants before the study began. Hong Kong Sports Institute Research Ethics Committee approved the experimental protocol, and the rights of the participants were protected. All tests were conducted in a temperature-controlled and humidity-controlled chamber (Welltech, Hong Kong, China) with ambient temperature at 31.4°C, relative humidity at 74%, and wind speed 0 m/s. Considering that cyclists always train in daytime during summer, this setting (data from the Hong Kong Observatory for the summers of 1981–2010) was able to simulate their training environment. Participants were also instructed to abstain from intense exercise in the 24-hour period prior to each session.

A randomised crossover design was adopted in this study, and the participants were required to perform three trials, each separated by 2–5 days. Prior to participation, all participants completed a maximal cycling test on an electromagnetically braked lower extremity cycle ergometer (Lode, Excalibur, Groningen, The Netherlands) to determine peak power output (PPO) and maximal oxygen uptake (VO_{2max}). The maximal cycling test was carried out at a fixed cadence of 90 rpm. Expired gas was analysed by a metabolic gas analysis system (MedGraphics CPX Ultima System; MGC Diagnostics

Corporation, Saint Paul, MN, USA). The maximal test began with participants pedalling at 150 W, then with an increase of 25 W in every minute until exhaustion.

Participants were required to complete two 35-minute exercise bouts separated by a 60-minute recovery period on a stationary cycling ergometer (SRM, Jülich, Germany) (Figure 1). The two exercise bouts (E1 and E2) included a 5-minute warm-up (1 minute at each of the following intensities: 125 W, 150 W, 175 W, 200 W, 75% PPO), a 15-minute session at a workload equal to 75% PPO, followed immediately by a 15-minute time-trial (TT1 and TT2). The power output of each trial was recorded by the cycling ergometer. Participants were only allowed to access the test time, and no external feedbacks were provided during the testing session. After each exercise bout, a 5-minute cool-down at 40% PPO immediately followed. In addition, a carbohydrate beverage was provided prior to (6% carbohydrate content, 3 mL/kg body mass) and in between (6% carbohydrate content, 15 ml/kg body mass) exercise bouts in a single session.⁸ One familiarisation session about the whole testing procedure was held to minimise any learning effect during the study. There were at least 48 hours between the maximal test, familiarisation session, and the three experimental trials.

Recovery treatments

Three recovery treatments, each lasting 15 minutes, were adopted in these three trials in randomised order: CWI, CCT, and ACT as the control. During CWI, participants were submerged in an inflatable water bath in a seated position with water level at midsternal and with cycling shorts on. Water temperature was maintained at 15°C with a designed water cooling machine (iCool LITE; iCoolSport, Queensland, Australia). A portable thermometer (Thermo Hygrometer, Yorter, Hong Kong, China) was also placed at the centre of the bath without touching the participant to monitor water temperature. For CCT, a cold compression system (Game Ready; CoolSystems, Concord, CA, USA) was used, and the compression level was standardised across treatment sessions. The ankle and thigh of both lower extremities were the target cooling sites and were bound with cold compression wraps. The wrap temperature was maintained at 15°C and with standardised rhythmic compression at high-level setting. Four portable thermometers (Yorter, Hong Kong, China) were placed in the wraps for monitoring and temperature adjustment throughout the whole treatment. In the ACT session, participants cycled at 40% of PPO. After the 15-minute recovery treatments, participants passively rested in the chamber with the same temperature and humidity settings until the start of the second session to simulate the resting in training or racing venue between exercise bouts.

Performance monitoring

Participants were required to swallow an ingestible core temperature sensor (CorTemp; HQ Inc., Palmetto, FL, USA) 1

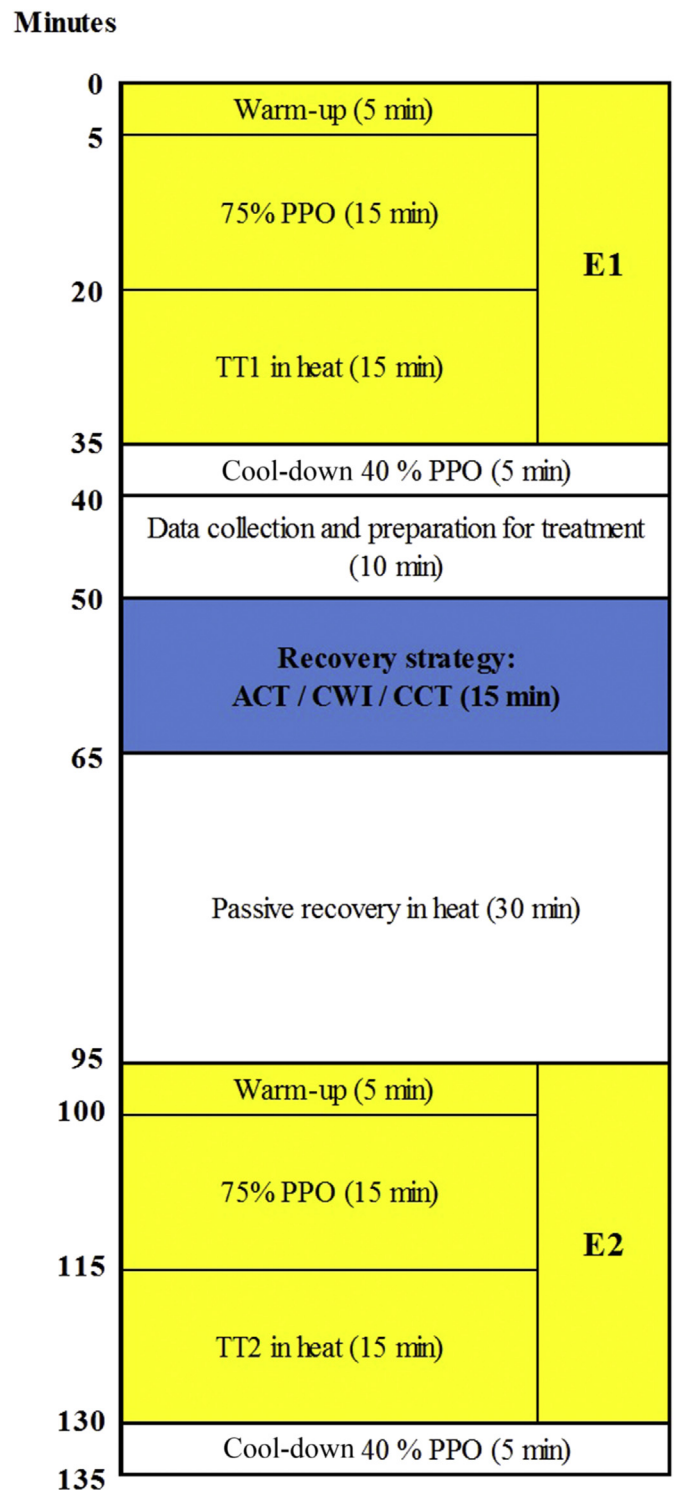


Figure 1. Timeline for the two 35-minute exercise bouts. Each bout of exercise (E1 and E2) included 5 minutes of warm-up, followed by 15 minutes of cycling at 75% peak power output (PPO) and 15 minutes' time trial (TT) in heat at maximal effort. There was a 60-minute rest period between E1 and E2, which included 5 minutes of cool-down at 40% PPO, 10 minutes of preparation for treatment, 15 minutes of recovery treatments, and 30 minutes of passive recovery in heat. ACT = active recovery treatment; CCT = cold compression therapy; CWI = cold water immersion.

hour prior to each session for monitoring of the core body temperature. Heart rate was continuously monitored by Polar heart rate monitor (Polar Electro Oy, Kempele, Finland). Blood lactate level was measured by Lactate Pro blood lactate analyser (Arkray Inc., Shiga, Japan), rating of perceived exertion (RPE) on a scale from 6 (no exertion) to 20 (maximal exertion)²⁰ and thermo sensation on a scale from 0 (unbearably cold) to 8 (unbearably hot)²¹ were recorded at a 5-minute intervals during the recovery treatments.

Statistical analysis

All dependent variables were tested for normality using a Shapiro–Wilk's test, unless otherwise indicated. A two-way repeated-measures analysis of variance (ANOVA) was used and Bonferroni *post hoc* test with correction was conducted to ascertain any significant changes for all the testing parameters: power output, core body temperature, blood lactate, RPE, thermal sensation scale, heart rate; between different treatments: ACT, CWI, CCT. Statistical analyses were conducted using SPSS computer software (Version 18.0; SPSS Inc., Chicago, IL, USA). All significance levels were set at $p < 0.05$.

Results

Power output

There was no significant difference between trial TT1 and TT2 ($p = 0.551$) for the three different recovery treatments. The absolute values of power output are shown in Table 1.

Core body temperature

Repeated-measures ANOVA was conducted to evaluate the hypothesis that there was a significant difference in core body temperature between post-TT1 and during treatment ($p < 0.001$) for the three different recovery treatments. No significant differences of the core body temperatures were found ($p = 0.391$) between pre-E1 and pre-E2. The core body temperature at the end of TT1 and TT2 were $38.64 \pm 0.82^\circ\text{C}$ and $38.32 \pm 0.88^\circ\text{C}$, respectively, for all testing trials. The core body temperature at different time points are shown in Figure 2, whereas the core body temperature during the two time-trial bouts are shown in Table 2.

As shown in Figure 2, core body temperatures were significantly lower at 15 minutes during the CWI recovery

sessions compared with CCT ($p = 0.011$). Also, significantly lower core body temperature was noted immediately after the recovery protocol for CWI when compared with ACT ($p = 0.033$).

Blood lactate

Lower blood lactate levels at post-TT1 and post-treatment were noted, with an average of -66% for all three recovery treatments. Significantly lower blood lactate values were recorded immediately after the recovery treatment for ACT (-75%) when compared with CCT (-62%) and CWI (-62%). Detailed values and trends for blood lactate at different time points are shown in Table 3 and Figure 3.

Rating of perceived exertion

There were no significant differences for RPE between the three recovery treatments at TT1 ($p = 0.538$, Kruskal–Wallis test) and TT2 ($p = 0.594$, Kruskal–Wallis test). The average RPE values for TT1 and TT2 are shown in Table 4. The RPE was recorded on a scale of 6–20 with 20 being the maximal exertion.

Thermal sensation scale

The thermal sensation scale during recovery treatments for CWI, CCT, and ACT were 2.64 ± 1.18 , 3.25 ± 0.76 , and 4.31 ± 1.03 , respectively. The thermal sensation scale ranges from 0 (unbearably cold) to 8 (unbearably hot).

Heart rate

Significantly lower heart rates were recorded after the 1-hour rest period compared with heart rates when exercises ended for all recovery treatments ($p < 0.001$). The ANOVA indicates no significant differences for the percentage change in average heart rate at all time points in the testing with regard to different recovery treatments ($p = 0.178$). The average heart rate during the two time-trial sessions are shown in Table 5.

Discussion

The aim of this study was to determine whether CCT intervention would provide the same effect as CWI and ACT treatment on recovery in a hot environment. It was hypothesised that CWI, ACT, and CCT should have no significant differences in recovery effect by comparing cycling performance after a rest interval in between sessions.

The postrecovery temperatures for all CCT, CWI, and ACT strategies were significantly lower compared with the pre-treatment temperature, which assists in releasing thermal strain. Although ACT allows blood lactate level to decrease at a faster rate than CWI and CCT during the recovery treatments, there were no significant differences between the blood lactate level for the three strategies before the athletes started the second time-trial bouts, implying that athletes had sufficient preparation for the next training or racing bouts. This can

Table 1
Average power output during the two time-trial bouts (TT1 and TT2) for the three different recovery treatments.

	Average power output (W)	
	TT1	TT2
Cold water immersion	221 ± 16	225 ± 22
Cold compression therapy	219 ± 24	217 ± 30
Active recovery treatment	227 ± 18	217 ± 27

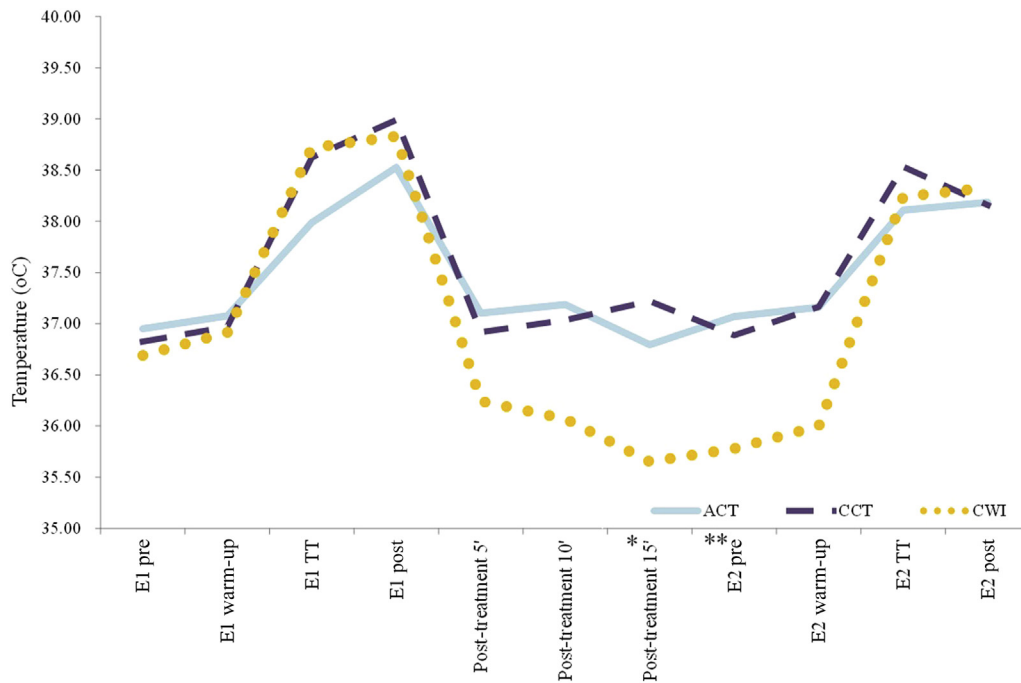


Figure 2. Core body temperature measured immediately before two exercise bouts (E1 pre, E2 pre), during warm-up (E1 warm-up, E2 warm-up), during the two 15-minute time-trial bouts (E1 TT, E2 TT), immediately after two exercise bouts (E1 post, E2 post), and 5 minutes, 10 minutes, and 15 minutes after recovery treatments (post-treatment 5', 10', 15'). * Significant difference between CWI and CCT, $p < 0.05$. ** Significant difference between CWI and ACT, $p < 0.05$. ACT = active recovery treatment; CCT = cold compression therapy; CWI = cold water immersion.

Table 2
Core body temperature during the two time-trial bouts (TT1 and TT2) for the three different recovery treatments.

	Core body temperature (°C)	
	TT1	TT2
Cold water immersion	38.72 ± 0.4	38.24 ± 0.51
Cold compression therapy	38.62 ± 0.83	38.53 ± 0.83
Active recovery treatment	37.99 ± 1.86	38.22 ± 1.38

Table 3
Blood lactate after first time-trial bout (post-TT1) and immediately after different recovery treatments.

	Blood lactate (mmol)	
	Post TT1	Post treatment
Cold water immersion	9.75 ± 2.35	3.73 ± 0.7*
Cold compression therapy	10.61 ± 2.53	4.04 ± 1.05*
Active recovery treatment	10.25 ± 3.17	2.25 ± 0.39*

* Significant difference between post-TT1 and post-treatment, $p < 0.05$.

be further demonstrated by the ability of the participants to maintain their time-trial performance and power output during the two time-trial bouts for all three recovery treatments. A novel finding of the present study is that CCT appears to provide similar effects for removing lactate from the circulation as ACT and CWI during the 60-minute rest between two exercise bouts. It is difficult to speculate upon the mechanism responsible from CCT. However, it is likely that CCT recovery treatment changes intramuscular hydrostatic pressure, and

produces alternating vasoconstriction and vasodilation, which is likely to alter blood flow to the immersed musculature for improving lactate removal.²² Further research is necessary to investigate the mechanism responsible for causing reduced accumulation in the CCT condition.

Some participants reported better thermal sensation for CCT, whereas others reported unbearable cold for CWI. Although not formally recorded, most of the participants were shivering during the first few minutes of the CWI recovery treatment. This can probably be explained by the significantly lower core temperature during the treatment. Although there is uncertainty on whether thermoreceptive neurons project to the nociception system, CWI may have caused an “overdose” of sensory information, which accounts for innocuous cold nociception.²³ Although CWI provided the greatest thermoregulatory benefit, it may impair exercise performance as part of a neural protective mechanism.²⁴ In contrast, during CCT, most of the participants felt cool but not unbearably cold. There was greater discomfort in thermal sensation for CWI compared with other strategies. CWI made body temperature even lower than the first exercise bouts in E1. In order to achieve the same body temperature as control, athletes may take a longer time for warm-up. We may need to take this into consideration especially when the resting time between two exercise bouts is short. Setup and availability of the three recovery treatments are concerns for coaches and athletes especially when they are racing or training on-field. CWI requires a big pool and a large amount of ice and water supply; drainage facilities are also needed for removal of ice water after usage. However, CCT is convenient in size, and some

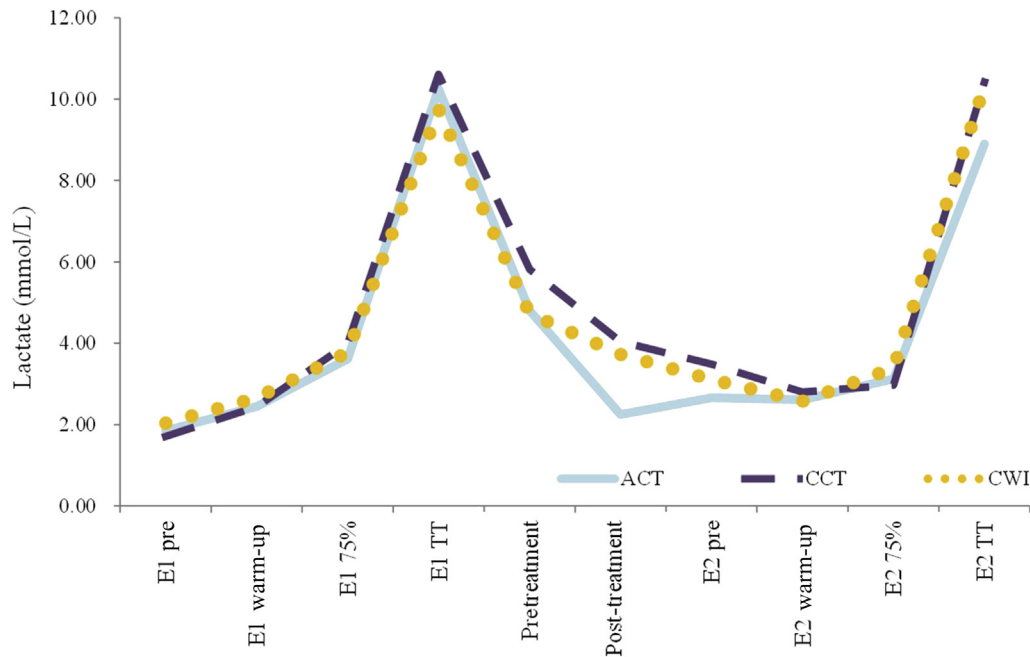


Figure 3. Blood lactate measured immediately before two exercise bouts (E1 pre, E2 pre), immediately after warm-up (E1 warm-up, E2 warm-up), immediately after 75% PPO bouts (E1 75%, E2 75%), immediately after two maximum time-trial bouts (E1 TT, E2 TT), and immediately before (Pretreatment) and after (Post-treatment) the recovery treatments. ACT = active recovery treatment; CCT = cold compression therapy; CWI = cold water immersion.

Table 4

Rating of perceived exertion (RPE) in TT1 and TT2 between the three different recovery treatments.

	RPE (scale 6–20)	
	TT1	TT2
Cold water immersion	18.88 ± 1.25	19 ± 1.31
Cold compression therapy	18.25 ± 1.83	18.5 ± 1.41
Active recovery treatment	18 ± 1.69	18.25 ± 1.98

Table 5

Average heart rate during the two time-trial bouts (TT1 and TT2) for the three different recovery treatments.

	Average heart rate (beats/min)	
	TT1	TT2
Cold water immersion	180 ± 11	184 ± 12
Cold compression therapy	186 ± 12	180 ± 17
Active recovery treatment	182 ± 11	179 ± 14

CCT machines are equipped with rechargeable batteries, therefore allowing treatment to be applied without requiring an external electrical power source. In addition, the amount of water and ice cubes required for CCT is significantly smaller than that for CWI.

ACT is a convenient method of recovery for most of the training and racing conditions, as the equipment and space needed are exactly identical to the training and racing conditions. However, in some competitions, because of limited space and a packed schedule, athletes have no access to race routes or venues, which makes ACT sometimes impossible. Also, ACT causes progressive glycogen depletion,²⁵ as it causes the breakdown of glycogen in Type I muscle fibres and

has no effect for resynthesis of glycogen in Type II muscle fibres.²⁶ Therefore, special attention needs to be given for replenishment of glycogen if ACT is adopted between two prolonged and close exercise bouts.

Conclusion

The current findings suggest that CCT, CWI, and ACT are all useful recovery treatments to allow athletes to prepare between two training bouts. However, CWI may cause thermal discomfort during treatment and lower the core temperature of athletes to below pre-exercise value; active recovery causes progressive glycogen in Type I muscle fibres, whereas CCT requires special equipment. In order to find the best daily recovery treatment, availability of facilities, athletes' preferences, duration of exercise, and rest should be taken into account.

Conflicts of interest

All contributing authors declare no conflicts of interest.

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