

# Does the Time Frame Between Exercise Influence the Effectiveness of Hydrotherapy for Recovery?

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An increase in research investigating recovery strategies has occurred alongside the increase in usage of recovery by elite athletes. Because there is inconsistent evidence regarding the benefits of recovery on performance, it is necessary to examine research design to identify possible strategies that enhance performance in different athlete settings. The purpose of this review is to examine available recovery literature specifically related to the time frame between performance assessments to identify considerations for both research design and practical use of recovery techniques.

**Keywords:** exercise performance, exercise recovery, hydrotherapy

There has been an increase in the research conducted examining the effects of recovery on performance, physiological variables, and more recently mechanisms of action. There are a small number of reviews examining usefulness of recovery,<sup>1</sup> physiological and biochemical effects,<sup>2,3</sup> and performance effects in various sports.<sup>3</sup> However, the purpose of this review is to examine recovery research in a time-dependent manner. In many instances, the use of recovery is determined by the time frame between the next training session or subsequent event. By examining research with varying time frames used to assess recovery effectiveness, it is possible to gain insight into which recovery modalities may be useful depending not only on the time between exercise, but also on the type of exercise performed. This can ultimately provide practical information for elite athletes/coaches and guide both directions and methodology for future research.

Due to space limitations, the focus of this review will be on performance-based research; thus, only research that has examined aspects of athlete performance will be discussed. The time frames included are as follows: (1) less than 60 min between exercise bouts; (2) between 1 h and less than 24 h; (3) studies utilizing repeated performance assessments over time; (4) studies utilizing repeated performance assessments *and* repeated recovery; and (5) studies that have examined repeated performance assessments, repeated recovery, *and* repeated exercise (ie, replication of competition setting).

## Less Than 60 Minutes Between Bouts of Exercise

Schniepp et al<sup>4</sup> examined two sprint cycling efforts with either cold water immersion (15 min in 12°C up to the iliac crest) or passive rest separating the two maximal efforts (each effort lasting approximately 30 s). The second sprint effort was completed immediately after the cold water immersion (ie, time frame of 0 min) and did not include a warm-up. Cold water immersion resulted in a reduction in maximum and average power of 13.7 and 9.5%, and the control condition resulted in decreases of only 4.7 and 2.3%, respectively. Thus, performance was significantly reduced following cold water immersion. Similarly, Crowe et al<sup>5</sup> reported reduced peak power, total work, and postexercise blood lactate compared with passive rest when cold water immersion (15 min at 13–14°C) was performed between two 30 s maximal cycling efforts separated by 1 h.

However, cold water immersion (5 min, 14°C) has been shown to maintain endurance cycling performance in the heat, when bouts of exercise were separated by 15 min.<sup>6</sup> Cold water immersion resulted in significantly lower core temperatures when compared with seated recovery in the heat and this lowering of core temperature may explain the resultant improvement in subsequent 4 km time trial performance.<sup>6</sup> The same research group conducted a similar study examining repeat cycling performance in the heat, where on this occasion the time between bouts was 20 min.<sup>7</sup> Two 1 km time trials were performed with cold water immersion (5 min, 14°C) or passive rest for 20 min occurring between bouts. In this study, cold water immersion had no effect on core temperature, maximal isometric concentric torque, or cycling performance; however, muscle temperature was lower in the cold water immersion group. The differences between the current study<sup>7</sup> and that of the previous one,<sup>6</sup> may be related to the low core temperature before immersion (as the result of only a 1 km trial compared with 25 min constant pace) and the shortened duration of the repeat effort (1 km time trial compared with 4 km time trial).

Parouty et al<sup>8</sup> investigated the effects of the same cold water immersion protocol (5 min, 14°C) on two 100 m swimming efforts separated by 30 min in well-trained swimmers. Cold water immersion resulted in a “likely” decrease in swimming performance (1.8%), despite a subjective perception of improved recovery. Again, this may be related to the short time frame between immersion and performance, the short duration of the subsequent performance (ie, 100 m sprint swimming), and the likely lack of rise core temperature during swimming.

Vaile et al<sup>9</sup> compared a longer duration of cold water immersion (15 min, 15°C) to that of active recovery between two 35 min cycling efforts in the heat (40 min between cycling bouts). Performance following active recovery significantly declined (1.81%), whereas performance following cold water immersion was unchanged (0.10%). Compared with active recovery, cold water immersion resulted in lower core temperatures and lower blood flow to the arms and legs, potentially explaining the enhanced performance.

Peiffer et al<sup>10</sup> examined the effect of different durations of cold water immersion (5, 10, or 20 min in 14°C) and 20 min of rest on maximal isometric and isokinetic torque 55 min after a time-to-exhaustion cycling test. Isometric and isokinetic torque were lower for all conditions immediately postexercise and 55 min postexercise, demonstrating no effect of recovery. Whereas the time between the end of exercise and subsequent muscle function testing was 55 min, the water immersion was per-

formed 25 min after the end of exercise. This resulted in a reduced time between water immersion and functional testing, which may have influenced the results and/or a greater warm-up before testing may have been required. In addition, the nature of the subsequent testing (neuromuscular testing on a Biodex), was not designed to measure performance and may have been influenced negatively by the low muscle temperature. If the subsequent testing took the form of a longer cycling effort, the lower core and muscle temperatures may have been advantageous.

Vaile et al<sup>11</sup> conducted a study similar to the above-mentioned study and examined different water immersion *temperatures* (15 min of intermittent immersion in 10°C, 15°C, and 20°C; continuous immersion in 20°C; and active recovery). Two 30 min cycling bouts performed in the heat were separated by 60 min, with one of the five recovery strategies performed immediately after the first exercise bout. All water immersion protocols significantly improved subsequent cycling performance when compared with active recovery.

The majority of published recovery studies utilize less than 60 min between exercise bouts. This is most often due to time efficiency for subjects and to maximize the potential of inducing fatigue in the control condition. This research may be useful for sports that involve a half-time break in play or in which athletes may compete more than once in a short time period (eg, swimmers in competing in multiple events).

There appears to be significant benefit of performing cold water immersion between exercise performed in the heat. There may also be benefits in thermoneutral environmental conditions on the proviso that the recovery does not occur too proximal to the subsequent exercise bout. In addition, the use of cold water immersion before maximal short duration sprinting is contraindicated due to a lowering of muscle temperature and a reduction in the muscles' force-generating capacity. A number of studies do not incorporate a warm-up preceding the second exercise bout and therefore do not replicate a real-life performance situation. When cold water immersion is performed between two bouts of exercise with a short duration between bouts, the recovery essentially acts as precooling for the second bout. Thus, based on precooling research, a significant performance improvement may be seen in endurance exercise in warm-to-hot conditions.<sup>12</sup>

## Between 1 Hour and 24 Hours

In a study investigating a dose-response effect of contrast water therapy, Versey et al<sup>13</sup> reported substantially improved cycling time trial and sprint performance following 6 min of contrast water therapy (hot water: 38.4°C; cold water: 14.6°C; 1 min rotations) when compared with control (passive rest). The time between cycling bouts was 2 h and the duration of each cycling bout was 75 min. Twelve minutes of cold water immersion also improved sprint total work and peak power. There was no improvement in repeat performance with 18 min of contrast water therapy, indicating a dose-response relationship does not exist under these conditions. The same research group repeated the above study with trained runners using identical water immersion times and temperatures and the same time between exercise bouts (2 h) (unpublished observations). However, in this instance, the first bout consisted of a 3000 m time trial and 8 × 400 m intervals. The second bout of exercise was a 3000 m time trial. The results of this study again did not show a dose-response

relationship between running performance and contrast water therapy; however, contrast water therapy for 6 min improved performance, whereas 12 and 18 min did not. Importantly, this study was performed outdoors in an environmental temperature of 14.9°C and the increased duration of cold water exposure may have reduced the potential benefits of longer water immersion durations. Therefore, benefits of longer duration contrast water therapy may potentially occur in warmer environments.

However, Hamlin<sup>14</sup> found contrast water therapy to have no beneficial effect on performance during repeated sprinting. Twenty rugby players performed two repeated sprint tests separated by 1 h; between trials, subjects completed either contrast water therapy or active recovery. Even though substantial decreases in blood lactate concentration and heart rate were observed following contrast water therapy, compared with the first exercise bout, performance in the second exercise bout was decreased regardless of intervention.<sup>14</sup>

Coffey et al<sup>15</sup> investigated the effects of three recovery interventions (active, passive, and contrast water therapy) on repeated treadmill running performance separated by 4 h. Contrast water therapy was associated with a perception of increased recovery. However, performance during the high-intensity treadmill running task returned to baseline levels 4 h after the initial exercise task regardless of the recovery intervention performed.

Lane and Wenger<sup>16</sup> investigated the effects of active recovery, massage, and cold water immersion on repeated bouts of intermittent cycling separated by 24 h. Cold water immersion resulted in enhanced subsequent performance when compared with passive recovery, active recovery, and massage.<sup>16</sup>

When examining the effect of various recovery strategies (passive, active, cold water immersion, contrast water immersion), King and Duffield<sup>17</sup> reported no significant effects of strategies on performance during a simulated netball circuit (vertical jump, 20 m sprint, 10 m sprint, and total circuit time). However, effect sizes showed trends for an ameliorated decline in sprint performance and vertical jumps with both cold water immersion and contrast water immersion. The period between testing sessions was 24 h, again suggesting that complete recovery may have occurred before repeat testing. It is also possible that the water immersion protocols were not substantial enough to have had an effect, with immersion to the iliac crest only and showers used for the hot water exposure in the contrast water therapy. This may suggest that muscle temperature is a key factor when considering the timing of recovery strategies.

From the literature presented above, it appears that the shorter the time frame between exercise (when the range is 60 min to 24 h), the greater the potential for recovery to enhance performance. Further, there are differences in methodology between studies that report a significant beneficial effect of recovery and those that do not. Coffey et al<sup>15</sup> and King and Duffield<sup>17</sup> both used protocols that contain two to three times more hot than cold water, immerse only to the iliac crest, and did not have an effect on performance. The studies by Versey et al<sup>13</sup> utilized identical ratios (1:1) and included whole body (excluding the head) immersion, thereby maximizing the effects of hydrostatic pressure, which may have accounted for the differing results. In addition, a number of studies that do not show an effect of water immersion on recovery have not induced a change in performance in the control condition. This may indicate that recovery occurred in the given time frame, the baseline exercise task was not sufficiently fatiguing, and/or the subjects did not provide a maximum effort knowing that a subsequent test was to follow.

## Multiple Performance Tests Over Time

Bailey et al<sup>18</sup> investigated the influence of cold water immersion on indices of muscle damage. Cold water immersion (10°C for 10 min) or passive recovery was administered immediately following a 90 min intermittent shuttle run protocol. The authors concluded that cold water immersion was a highly beneficial recovery intervention, finding a reduction in muscle soreness and a reduced decrement in performance at both 24 and 48 h postexercise.

In a randomized controlled trial, Sellwood et al<sup>19</sup> investigated the effect of ice-water immersion on indicators of delayed onset muscle soreness (DOMS). Following a leg extension eccentric exercise task (5 × 10 sets at 120% concentric 1RM), participants performed either 3 × 1 min water exposure separated by 1 min in either 5°C or 24°C (control) water. Pain, swelling, muscle function (one-legged hop for distance), maximal isometric strength, and serum creatine kinase were recorded at baseline, 24, 48, and 72 h after damage. The only significant difference observed between the groups was lower pain in the sit-to-stand test at 24 h postexercise in the ice-water immersion group.<sup>19</sup> In this study, maximal isometric strength decreased by 11.5 N·m in the cold water immersion group and 17.4 N·m in the control condition, although this was not statistically significant. However, the use of 24°C as a control temperature is questionable, as thermoneutral water temperature (approx. 35°C) is considered more appropriate. It is possible that the control temperature was more suitable for recovery than the intervention water temperature (5°C).

In a more recent study investigating the effects of contrast water therapy on the symptoms of DOMS and the recovery of explosive athletic performance, recreational athletes completed a muscle-damaging protocol on two separate occasions in a randomized cross-over design.<sup>20</sup> Following contrast water therapy, isometric force production was not significantly reduced below baseline levels throughout the collection period (at 24, 48 and 72 h) when compared with control; however, following passive recovery, peak strength was significantly reduced from baseline by 14.8 ± 11.4%, 20.8 ± 15.6%, and 22.5 ± 12.3% at 0, 24, and 48 h respectively.<sup>20</sup>

Paddon-Jones and Quigley<sup>21</sup> induced muscle damage in both arms (64 eccentric elbow flexions) and then one arm was immersed in 5°C water for 5 × 20 min, with 60 min between immersions, while the other served as a control. No differences were observed between treated and nontreated arms during the next 6 d for isometric and isokinetic torque, soreness, and limb volume.<sup>21</sup> Again, a 5°C water temperature may not be suitable for recovery from severe eccentric muscle damage.

Jakeman et al<sup>22</sup> reported no benefit of 10°C water immersion following eccentric muscle damage in active females. Subjects completed 10 min of cold water immersion to the iliac crest and repeat measures of creatine kinase concentration, perceived soreness, maximal voluntary contractions, and vertical jump height were made at 1, 24, 48, 72, and 96 h postexercise. In this instance, there was a time effect for all variables, indicating the presence of muscle damage and a change in the control group. This study suggests that there was no clear benefit of cold water immersion in enhancing recovery in this population.

The majority of studies that have investigated recovery over repeated time points have involved muscle-damaging exercise as the exercise stimulus. This is due to the delayed recovery that occurs following exercise-induced muscle damage. As can be seen above, there is conflicting evidence regarding the efficacy of cold water

immersion for recovery from muscle damage. This may be due to methodological differences, such as water temperature, duration of exposure, depth of exposure, degree of muscle damage/fatigue, training status of the subject, types of performance assessments, and whether appropriate temperatures are used during control.

From the available literature, it appears that temperatures below 10°C may be ineffective. In addition, because of the small number of studies suggesting potential benefits, more research is needed to investigate contrast water therapy in enhancing recovery from muscle damage.

## Multiple Performance Tests with Repeated Recovery

Vaile et al<sup>23</sup> examined the effects of three hydrotherapy interventions on the physiological and functional symptoms of DOMS. A total of 38 strength-trained males completed two experimental trials separated by 8 mo in a randomized crossover design. One trial involved passive recovery, and the other consisted of a specific hydrotherapy protocol each day for a 72 h period postexercise, as follows: either (1) cold water immersion ( $n = 12$ ), (2) hot water immersion ( $n = 11$ ), or (3) contrast water therapy ( $n = 15$ ).<sup>23</sup> For each trial, participants performed a DOMS-inducing leg press protocol followed by either passive recovery or one of the hydrotherapy interventions for a total of 14 min. Overall, cold water immersion and contrast water therapy were found to be effective in reducing the physiological and functional deficits associated with DOMS, including improved recovery of isometric force and dynamic power and a reduction in localized edema.<sup>23</sup> Although hot water immersion was effective in the recovery of isometric force, it was ineffective for recovery of all other markers compared with passive recovery.

Eston and Peters<sup>24</sup> investigated the effects of cold water immersion (of the exercised limb in 15°C for 15 min) on the symptoms of exercise-induced muscle damage following strenuous eccentric exercise. The exercised arm was placed in cold water (15°C for 15 min) every 12 h for 3 d. Although isometric strength was greater than control at 24 ( $78.3 \pm 21.4$  vs  $73.0 \pm 29.0$ ), 48 ( $92.5 \pm 31.2$  vs  $81.3 \pm 52.1$ ), and 72 h ( $112.3 \pm 27.2$  vs  $86.4 \pm 45.3$ ), this was not statistically significant, most likely due to the high variation in subject strength values. The authors found creatine kinase activity to be lower and relaxed elbow angle to be greater for the cold water immersion group at 48 and 72 h following the eccentric exercise, concluding that the use of cold water immersion may reduce the degree to which the muscle and connective tissue unit becomes shortened after strenuous eccentric exercise.<sup>24</sup>

The effectiveness of cold water immersion (12 min at 15°C) in enhancing recovery and its impact on the repeated bout effect were examined by Howatson et al.<sup>25</sup> Sixteen recreationally active males performed two bouts of drop jump exercise separated by 14 to 21 d. Cold water immersion or rest was provided immediately after the first bout of exercise and 24, 48, and 72 h postexercise. Cold water immersion had no effect on maximal voluntary contraction, creatine kinase, thigh girth, or range of motion. Although there were significant time effects for most variables and evidence of the repeated bout effect, cold water immersion did not influence markers of muscle damage or the magnitude of the repeated bout effect. The effectiveness of two water immersion strategies (cold water immersion and contrast water therapy) on recovery from simulated team sport performance was assessed across a 48 h period.<sup>26</sup> Each subject completed three 3-d testing trials with either cold water

immersion, contrast water immersion, or passive recovery completed immediately after the initial exercise bout and again at 24 h after exercise. Performance (20 m sprint, time taken to complete 10 × 20 m sprints, and leg extension isometric force) was assessed before exercise and 48 h after exercise. Cold water immersion (2 × 5 min in 10°C) was significantly better than both contrast water immersion (2 min cold in 10°C, 2 min in 40°C × 3) and control in reducing ratings of muscle soreness and reducing decrements in both isometric leg extension and flexion and resulted in a more rapid return of sprint performance to baseline value. Contrast water immersion only improved muscle soreness at 24 h when compared with control.

Even though there are contrasting findings, similar to the previous section on repeat assessments, it appears that the use of repeated recovery on a daily basis may provide additional benefits and result in significant performance improvements.

## Multiple Performance Tests with Repeated Recovery and Repeated Exercise

The effects of three hydrotherapy interventions on next-day performance recovery following strenuous training has been investigated.<sup>27</sup> A total of 12 male cyclists completed four experimental trials differing only in recovery intervention: cold water immersion, hot water immersion, contrast water therapy, or passive recovery. Each trial comprised five consecutive exercise days (105 min in duration, including 66 maximal effort sprints) followed by hydrotherapy on each day. After completing each exercise session, participants performed one of the four recovery interventions (in a randomized crossover design). Sprint (0.1–2.2%) and time trial (0.0–1.7%) performance was enhanced across the 5 d trial following both cold water immersion and contrast water therapy when compared with hot water immersion and passive recovery. Overall, cold water immersion and contrast water therapy improved recovery from high-intensity cycling when compared with hot water immersion and passive recovery, with athletes better able to maintain performance across a 5 d period.<sup>27</sup>

Only one study has investigated the effect of hot water immersion on postexercise recovery. Viitasalo et al<sup>28</sup> incorporated three 20 min warm (approx. 37°C) underwater water-jet massages into the training week of 14 junior track and field athletes. The results indicated an enhanced maintenance of performance (assessed via plyometric drop jumps and repeated bounding) following the water treatment, indicating a possible reduction in DOMS.

Robey et al<sup>29</sup> reported no effect of contrast water therapy or static stretching on leg strength, rowing performance, and indicators of muscle damage in both club-level and elite rowers. Stair running was used to induce muscle damage and recovery was completed immediately after, and 24 and 48 h following exercise. Performance tests were completed 24, 48, and 72 h postexercise, and athletes continued to train during the 72 h following the exercise period. As leg extension peak torque was unchanged following 24 h of recovery in all groups, it appears that recovery was complete at 24 h in these athletes (rowing performance was measured at 72 h only and also showed no statistical differences). Other possible explanations for the lack of effect include showers were used for the hot component of the contrast water therapy, subjects immersed to their waist in the cold water, and a 2:1 ratio of hot:cold exposure was used.

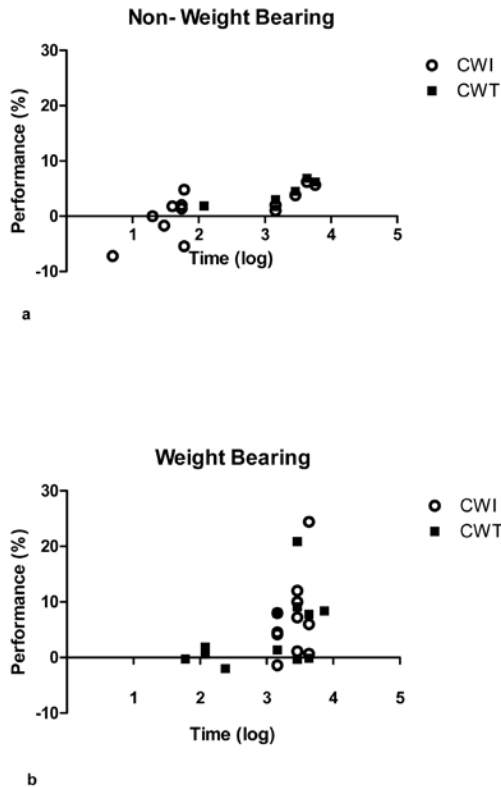
The effectiveness of three recovery strategies (carbohydrate and stretching, cold water immersion, and full leg compression garments) was examined before and after a 3 d tournament-style basketball competition in state-level basketball athletes.<sup>30</sup> Recovery was performed each day, and the athletes played one full 48 min game per day. Sprint, vertical jump, and agility decreased across the 3 d tournament, indicating accumulated fatigue. Cold water immersion was substantially better than other strategies in maintaining 20 m acceleration. Cold water immersion and compression showed similar benefits in maintaining line-drill performance when compared with carbohydrate and stretching. Rowsell et al<sup>31</sup> conducted a similar study in high-performance junior soccer players, with four matches played over 4 d and recovery completed after each match. No effect of cold water immersion was observed when compared with thermoneutral water immersion on indicators of soccer performance. However, the perception of fatigue and muscle soreness was lower in the cold water immersion group. In this instance, cold water immersion was conducted for 5 min in 10°C, which is almost identical to the Montgomery et al<sup>30</sup> paper. It is possible that the different findings may be explained by either the different performance tests utilized, the difference in water immersion (seated vs standing and thus lower hydrostatic pressure), differing levels of fatigue, and/or the differences in the nature of fatigue in soccer and basketball.

The study designs utilized above most represent real-life training and competition environments in many elite athletes. Again, there is limited research on noneccentric exercise, with the exception of Vaile et al,<sup>27</sup> yet it appears from this study that cycling exercise performed at a high intensity for a long duration may benefit from recovery when the recovery is appropriate in temperature, duration, and depth of exposure. Again, there is some conflicting evidence for cold water immersion and muscle damage, with some studies showing a positive effect and others showing no effect. Importantly, none of the above studies have demonstrated a negative effect of ice baths on performance. Again, further research is needed investigating the usefulness of contrast water therapy.

## Summary

From the studies reviewed above, some suggestions can be made regarding time frames between exercise and the efficacy of hydrotherapy for recovery. Figure 1 is a graphical representation of performance changes associated with cold water immersion and contrast water therapy relative to time. Not all of the reviewed papers could be included, as some did not provide adequate data, with key findings presented only in graphical format. Figure 1 is an attempt to identify time periods and possible benefits/detriments for recovery, but this does not take into consideration poor methodological designs or differences in the means of assessing performance. In Figure 1a and 1b, zero on the y-axis represents no performance effects of hydrotherapy compared with control. Data points above the line indicate performance improvements when compared with control, and thus data points below the line indicate that performance was lower after hydrotherapy when compared with the control condition. Due to the large range of time courses included, the time was log transformed. Figure 1a represents non-weight-bearing exercise (swimming and cycling), and Figure 1b represents weight-bearing activity (running, weight training, eccentric muscle damage models).





**Figure 1** — The percentage of performance change associated with cold water immersion (CWI) and contrast water therapy (CWT) relative to time. *Note.* Time frame between exercise has been log transformed.

Figure 1 demonstrates that the change in performance is considerably smaller in non-weight-bearing sports, most likely reflecting the type of performance tests. The majority of studies included in Figure 1b utilize eccentric exercise protocols, which cause moderate-to-severe muscle damage and the performance tests are usually based on force or torque measurements. Thus, these types of studies do not closely replicate the performance changes experienced by elite athletes. Figure 1a highlights the fact that when the time between exercise is short (less than 30–60 min), existing literature suggests that performance may be compromised. Again, this is likely due to the fact that most studies have utilized power or sprint tests as performance indicators. A short time frame between exercise bouts may still be efficacious for hydrotherapy if the subsequent performance task is of a longer duration or an appropriate warm-up is included.

Figure 1b highlights the fact that, due to the nature of eccentric exercise models, there is limited data on the use of recovery within short time frames. Much more data is available examining shorter time frames in non-weight-bearing exercise, such as cycling, possibly due to the expected faster recovery of performance and the absence of DOMS.

## Considerations for Research Design

From the examination of the above studies, it appears there are some differing results regarding the efficacy of water immersion for recovery. Many of these differences may be due to differences in methodology, and thus it is important to consider some recommendations for research design. Some considerations for future recovery research design and methodology follow.

- Investigate the highest level of athlete possible. Recreational or untrained subjects give little insight into well-trained or elite athlete responsiveness to recovery strategies.
- Ensure the exercise task results in a change in the control condition in order to adequately compare control and intervention trials.
- Utilize whole-body immersion with the subject standing if possible. Avoid the use of showers as a means of water therapy where possible.
- Use appropriate temperatures and duration for both immersion and control. Research that has found positive effects of water immersion utilize temperatures between 10 and 15°C for cold water and 38 and 40°C for hot water and durations of 5–20 min. It is recommended that at least 10 min of immersion is utilized.
- The ratio of hot:cold during contrast water therapy should be 1:1.
- Include thermoneutral water immersion (approx. 34.5°C) to control for the effects of hydrostatic pressure if examining and comparing the effect of temperature.
- Utilize appropriate performance measures that are relevant to elite athletes and have a low coefficient of variation. Include a variety of performance measures when possible.
- Include familiarization sessions for not only the performance tests, but also the water immersion protocols.
- Include a warm-up before all exercise and performance tests.
- Utilize whole-body exercise or large muscle groups to appropriately replicate sporting activities.
- Consider the type of exercise performed and the timing of recovery before the subsequent bout of exercise. For example, the use of cold water immersion before sprint activity is counterintuitive due to the relationship between muscle temperature and contraction velocity. In this instance, hot water immersion may be substantially more effective. These studies may give readers an inappropriate perception of cold water immersion.
- Further research is needed examining the potential benefits of contrast water immersion.
- Ideally, studies should replicate competition or training environments with repeat exercise and repeat recovery assessed.
- Studies should also attempt to quantify placebo effects and belief effects regarding hydrotherapy.

## Considerations for Practical Application

Based on published research and anecdotal information from athletes, a number of practical recommendations may be made.

- Consideration should be given to the amount of time until the next training session or competition. Is recovery necessary? What can be practically performed in the time frame? What strategies have scientific evidence to support their use in the given time?
- Does the exercise involve muscle damage? Repeating the recovery strategy on subsequent days may be beneficial and contrast water therapy may be a useful strategy.
- Is the athlete required to perform maximal, short-duration efforts? If so, cold water immersion before the effort will most likely be detrimental. Consideration must be given to the potential change in muscle and core temperature and whether that will enhance performance (as in precooling) or reduce performance.
- Use appropriate temperatures and duration for immersion. Research that has found positive effects of water immersion utilize temperatures of 10–15°C for cold water and 38–40°C for hot water.
- A duration of 14–15 min of either cold water immersion or contrast water therapy has been shown to improve performance in several studies.
- The ratio of hot:cold during contrast water therapy should be 1:1. Research that has shown positive performance effects has used seven rotations of 1 min hot and 1 min cold.
- Body size may influence duration of exposure due to higher or lower insulation effects from muscle and fat mass.
- The whole body should be exposed to cold (excluding the head) and athletes should be standing rather than sitting to maximize the hydrostatic pressure effects.
- If it is not possible to use temperatures approximating 10–15°C, benefits from higher temperatures (eg, 20°C) may be observed using longer durations of exposure.
- Consideration should be given to environmental temperature.
- Periodization of recovery may be important in many sports, whereby recovery is minimized during intensified training to increase fatigue and potentially adaptation. However, this may impair quality of training and may increase the risk of injury in sports involving eccentric activity and/or contact. Further, in sports competing regularly (eg, weekly), recovery is often needed to minimize fatigue and maximize recovery between competition and thus should be prioritized.

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