

Recovery after exercise: what is the current state of play?

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Recovery after exercise is an essential element of the training–adaptation cycle. The overall goal of postexercise recovery is to restore homeostasis in many of the body’s physiological systems. After exercise, fluids and fuels lost or consumed during exercise must be replaced, body temperature and regular cardiovascular function must be restored, and damaged tissue must be repaired. These events should all occur in a timely manner before the next training session or competitive event occurs. Our understanding of the physiological foundation of postexercise strategies is growing, and further research will help to refine how such strategies are used in practice. Other priorities for future research include (i) investigating methods to promote good sleep behavior in athletes, (ii) examining the effectiveness of combining different recovery interventions, and (iii) determining the optimum timing and frequency of when to adopt recovery strategies between training/competition and across the different phases of a season.

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Introduction

Postexercise recovery is one of the fundamental principles of exercise training. Interest in—and attention to—postexercise recovery has increased dramatically in the last two decades or so. Athletes (and the coaches and sport scientists who train them) look to the period of recovery between training sessions and competition to maximize marginal gains in performance and adaptation. Intense exercise often leads to fatigue, increased body temperature, dehydration, depletion of muscle glycogen and soft tissue damage. In turn, these events disrupt the nervous

and peripheral nervous systems, cardiovascular, thermo-regulatory, renal, endocrine and immune systems. The general goals for postexercise recovery are to restore homeostasis, replace fuels and fluids, repair the body’s tissues, and rest. To achieve these goals, athletes may choose various nutritional and physical interventions, including rehydration, carbohydrate and protein feeding, stretching, massage, hydrotherapies, whole-body cryotherapy, wearing compression garments and sleep (Figure 1).

Adaptation to training requires regular periods of intense but relatively brief physiological stress or fatigue, followed by longer periods of recovery. If training is too intense and/or not accompanied by enough recovery, athletes may experience underrecovery, and possibly overreaching. Overreaching is the buildup of training and/or training stress leading to temporary impairment of performance capacity, with (or without) psychophysiological indicators of maladaptation, which may require several days to week to restore performance capacity [46]. Conversely, if athletes incorporate adequate recovery into their training cycles, then this should lead to greater tolerance for training and positive physiological adaptations that underpin improvements in athletic performance (Figure 2).

The aims of this review are to provide a brief overview of the scientific basis of both established and emerging strategies for postexercise recovery and, where relevant, highlight recent developments in this research domain.

Nutritional interventions

Among the various postexercise strategies, nutritional interventions are arguably based on the strongest science. The section below discusses strategies for replacing fluids, restoring glycogen and stimulating muscle protein synthesis.

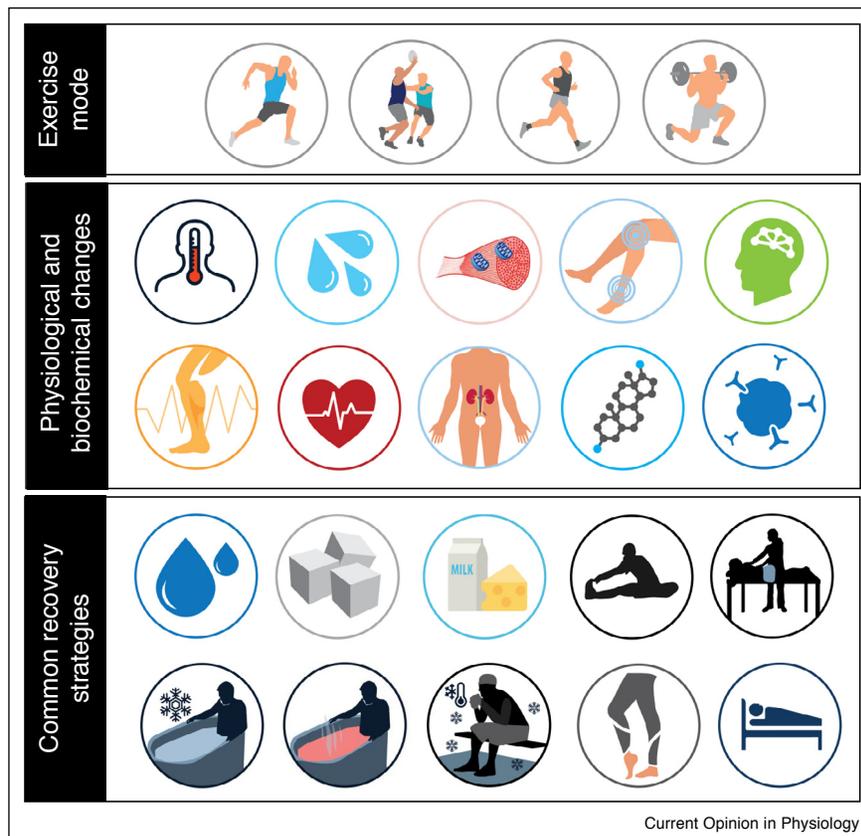
Fluid replacement

Changes in blood volume during exercise strongly influence cardiovascular function. Replacing lost fluids after exercise is, therefore, critical for restoring cardiovascular function. The key considerations for rehydrating after exercise are briefly outlined below. For more detailed information about rehydration after exercise readers are referred to the comprehensive review by Evans *et al.* [20*].

Volume

Athletes can assess their rehydration requirements after exercise simply by measuring nude body mass before and after exercise, and calculating the difference. Because

Figure 1



Intense exercise, whether it be anaerobic, aerobic, strength or team-based activity often leads to dehydration, depletion of muscle glycogen and soft tissue damage. In turn, these events disrupt the nervous and peripheral nervous systems, cardiovascular, thermoregulatory, renal, endocrine and immune systems. Athletes may choose a combination of nutritional and physical interventions to restore regular function after exercise.

athletes may continue to lose fluid for a brief period after exercise (as a result of sweating), it is recommended that they consume 150% of fluid lost during exercise [48].

Osmolality

Water is the most convenient fluid to drink after exercise. However, because water reduces blood osmolality, some of it is simply excreted, potentially resulting in negative fluid balance. Instead, consuming fluids containing 20–50 mmol/L sodium is the most effective (and palatable) for achieving positive fluid balance [61]. Addition of carbohydrates to water slows the rate of gastric emptying and fluid absorption. Fluid retention is greater after ingesting fluids with 3–12% glucose compared with water alone [49]. Higher carbohydrate content in fluids may lead to symptoms of gastrointestinal bloating [20*].

Rate of rehydration

Regularly replacing lost fluids in moderate volumes over a long period (i.e. 4–5 hours) results in better fluid balance compared with replacing lost fluids in large volumes over a shorter period (≤ 3 hours) [20*,39].

Alternative fluids

The effects of consuming milk or drinks containing protein are equivocal, with some studies showing a benefit [20*,59], and others reporting no benefit [20*,59] when compared with carbohydrate-electrolyte drinks. Drinks containing ≥ 250 mg caffeine [23] and 4% alcohol [60] cause greater urine output compared with water or electrolyte drinks. However, small amounts of sodium can offset the effects of alcohol on urine output after exercise [16].

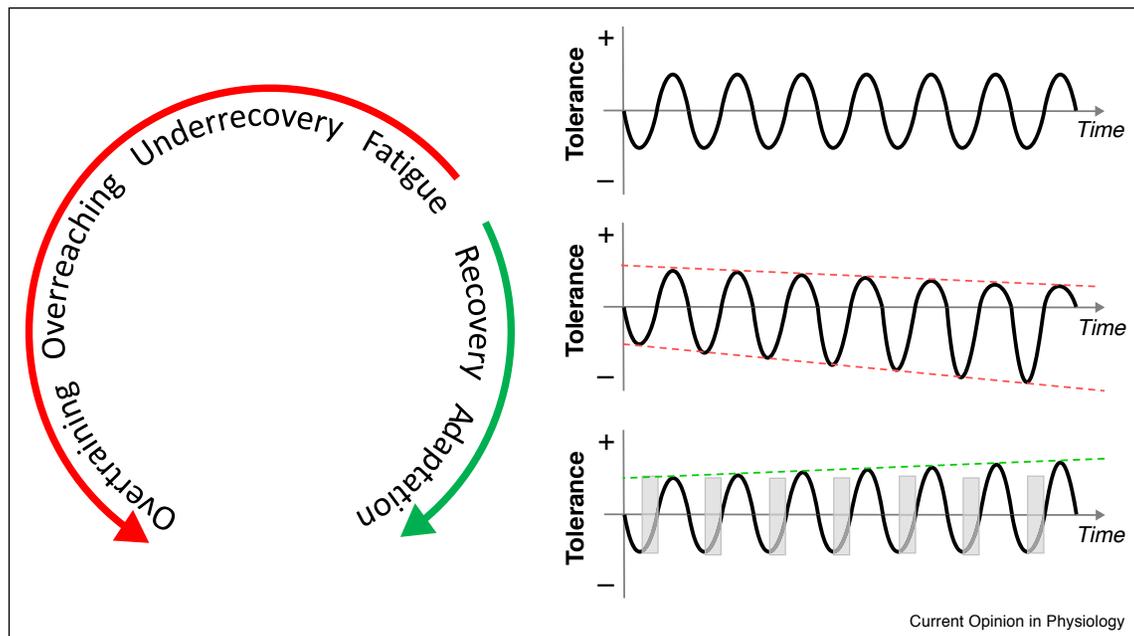
Combining fluids with food

The combination of adequate volumes of water and food achieves greater fluid balance compared with ingesting only electrolyte drinks [45], while combining electrolyte drinks and food is more effective than only water and food [21].

Specific rehydration needs

No research has specifically examined the effects of age or sex on rehydration after exercise. The limited evidence available indicates some possible sex differences in the

Figure 2



A schematic illustrating the fatigue–recovery continuum as it relates to tolerance of different training loads. See text for more explanation.

pattern of fluid replacement during exercise [3,72], and age-related differences in fluid retention at rest [76].

In summary, when fluid losses are small and extended recovery periods allow for ample consumption of water and food, aggressive rehydration is not necessary. However, when recovery time is brief, athletes need to focus more carefully on rehydrating, as thirst-driven fluid intake may not be enough to restore their fluid balance [20*].

Replacing glycogen

Glycogen is an important fuel source during intense exercise. Glycogen utilization increases with exercise intensity [68] and ambient heat during exercise [38]. The key considerations for planning diets to replace muscle and liver glycogen after exercise are briefly outlined below. For more detailed information about replacing glycogen after exercise, readers are referred to the comprehensive review by Burke *et al.* [11**].

Effects of preceding exercise and individual factors

Acute muscle glycogen depletion during exercise [77] and adaptation endurance training [30] result in faster rates of muscle glycogen resynthesis after exercise. Conversely, muscle damage during exercise reduces the rate of muscle glycogen resynthesis after exercise [4].

Amount of carbohydrate

With respect to the optimum amount of carbohydrate to consume after exercise, 0.7 g/kg/hour is the minimum [5],

whereas there is no additional benefit to consuming more than ~ 1.2 g/kg/hour [35]. Over the period of 24 hours after exercise, muscle glycogen resynthesis is similar after consuming 7 g/kg/day versus 11 g/kg/day [8], but carbohydrate intakes of 8–12 g/kg/day may be required to replace muscle glycogen after prolonged, intense exercise [11**].

Timing of carbohydrate intake

A period of 24 hours is usually required to restore muscle glycogen completely after intense exercise [11**]. The first 2 hours after exercise is a critical period for replacing muscle glycogen. Consuming carbohydrate immediately after exercise results in faster muscle glycogen resynthesis compared with ingesting carbohydrate 2 hours after exercise [37]. The benefits of ingesting carbohydrate immediately after exercise diminish over longer periods of recovery [51]. Rates of muscle glycogen resynthesis are also similar whether small amounts of carbohydrate are consumed every hour, or large amounts are eaten over longer intervals [9].

Type of carbohydrate

Consuming high glycemic index foods results in faster muscle glycogen resynthesis compared with low glycemic index foods [10]. There is no difference in the rate of muscle glycogen resynthesis between consuming solid versus liquid forms of carbohydrate [57], but carbohydrate drinks provide the additional benefit of rehydration. Combining dietary glucose and fructose for intakes

>1.2 g/kg/hour markedly enhances the rate of resynthesis of liver (but not muscle) glycogen compared with consuming glucose on its own. This strategy also alleviates potential gastrointestinal discomfort associated with glucose intake [24].

Other dietary additives

Co-ingesting 0.3–0.4 g/kg protein with 0.5–0.8 g carbohydrate/kg/hour enhances muscle glycogen resynthesis, whereas protein co-ingestion does not provide any extra benefit when combined with higher carbohydrate intakes (i.e. >1 g/kg/hour) [2]. There is mixed evidence for the benefits of consuming carbohydrate with other dietary agents such as creatine, caffeine and ketone esters [11^{••},34].

In summary, if athletes need to recover quickly between training sessions or competitive events, they are advised to consume high glycemic index food or drink as soon as practical after exercise. Consuming moderate amounts of carbohydrate and protein together will provide benefits for replacing muscle glycogen and stimulating muscle protein synthesis. Although frequent feeding is not necessarily more effective for replacing muscle glycogen, regular small meals may be easier for athletes to consume than less regular large meals.

Muscle protein synthesis

Muscle protein net balance (and muscle mass) depends on the balance between muscle protein synthesis and muscle protein breakdown. Exercise and nutrition stimulate greater rates of protein synthesis than breakdown in muscle [54]. Muscle protein net balance is, therefore, mainly determined by changes in the rate of muscle protein synthesis. However, by clearing damaged or aberrant proteins, muscle protein breakdown still plays an important role in remodeling of muscle tissue [67^{••}]. The key considerations for promoting muscle protein synthesis after exercise are briefly outlined below. For more detailed information about muscle protein synthesis after exercise, readers are referred to the comprehensive review by Trommelen *et al.* [67^{••}].

Amount of protein

Research indicates that consuming 20 g whey protein during recovery from exercise maximizes muscle protein synthesis, and minimal further increases occur in response to ingesting 40 g protein [75].

Type of protein

Consuming animal-based protein sources after exercise stimulates higher rates of muscle protein synthesis compared with plant-based protein sources [65]. Dose effects of animal-based protein on muscle protein synthesis have been established; whether similar dose effects exist for plant-based protein sources is currently unknown. Athletes who are vegetarians may be able to enhance

muscle protein synthesis after exercise by eating more (or multiple sources of) plant-based protein [67^{••}]. The dose effects of protein ingestion on muscle protein synthesis have been determined using isolated, rapidly digestible protein sources. It remains unknown if dose effects also occur in response to slow digestible protein. Consuming greater amounts of slow digestible protein could stimulate moderate, but more prolonged muscle protein synthesis [67^{••}].

Effects of other dietary constituents and factors

Most research on the influence of dietary protein on muscle protein synthesis has involved isolated protein; yet dietary protein is usually consumed as part of meals with various types of protein and other macronutrients. Co-ingesting protein with carbohydrate after exercise does not enhance muscle protein synthesis compared with consuming protein on its own [62]. Although it is yet to be determined, ingesting a mixed meal containing slowly digestible carbohydrate (and possibly fiber) could slow protein digestion and absorption kinetics, thereby delaying muscle protein synthesis [67^{••}]. The influence of fat in a protein-containing meal is currently uncertain [67^{••}]. Consuming large volumes of alcohol (twelve standard drinks) after exercise attenuates muscle protein synthesis [52]. Athletes who restrict their caloric intake to reduce body fat should consider increasing their daily protein intake above the recommended daily allowance of 0.8 g/kg/day to preserve muscle protein synthesis [53].

Influence of body mass, sex and aging

The effects of protein consumption after exercise on muscle protein synthesis are independent of body mass [43] and sex [71]. Older athletes—particularly females—may require more than 20 g protein after exercise to maximally stimulate muscle protein synthesis [67^{••}].

In summary, the optimal amount and type of protein to consume after exercise may depend on the timing of meals. Around 20 g of rapidly digestible protein is optimal for relatively short intervals between meals (i.e. 3–5 hours), whereas ≥ 40 g of slow digestible protein may be more appropriate for longer periods between meals (e.g. overnight) [67^{••}].

Other nutritional interventions

Research has investigated the efficacy of a wide range of other foods and supplements for reducing muscle damage after exercise. This research has been based on their anti-inflammatory and antioxidant properties, and to a lesser extent, their capacity to enhance muscle protein synthesis. There is relatively consistent evidence for the benefits of black currant extract, tart cherry juice, beetroot juice, branched chain amino acids, taurine and caffeine [27]. Foods and supplements for which there is mixed or inconclusive evidence include pineapple, pomegranate juice, watermelon juice, green tea,

curcumin, creatine, L-glutamine, β -hydroxy- β -methylbutyrate, vitamin D and n-3 poly unsaturated fatty acids [27]. There is currently insufficient evidence supporting the benefits of green algae extract, ginseng and ginger, while most research demonstrates no benefits of supplementation with protein and vitamins C and E for reducing delayed onset muscle soreness [27]. Most studies have provided these foods and supplements for a period of days or weeks before exercise; less research has supplied them during the postexercise recovery period. It remains uncertain if consuming them in the short-term after exercise provides the same benefits as regular consumption/supplementation. A key consideration in this regard is whether the benefits of these foods and supplements for reducing exercise-induced muscle damage outweigh any detrimental effects on chronic training adaptations [50].

Physical interventions

Various physical interventions have been developed for use in postexercise recovery. Some of these interventions (e.g. stretching, massage, hydrotherapy) have been used for a long time, whereas others (e.g. neuromuscular electrical stimulation, compression garments, vibration therapy, cryotherapy) have been adopted more recently. Compared with nutritional interventions, the physiological basis for these physical interventions is less well established.

Stretching

Stretching in its various forms (i.e. passive, active, dynamic, ballistic) involves mechanical stimulation of various anatomic structures (e.g. connective tissue and tendons, elements of the cytoskeleton and actomyosin crossbridges) together with activation of afferent pathways, inhibitory and excitatory reflexes with the nervous system [56]. From a functional perspective, stretching has been used in an attempt to restore strength and reduce soreness/pain during recovery from exercise [56]. However, the findings of a recent systematic review and meta-analysis do not support these anecdotal beliefs in the benefits of stretching [18^{*}]. Stretching may offer some modest benefits when it is combined with other recovery strategies (e.g. massage).

Massage

Massage, which involves manipulating tissues either manually (using fingers, hands and elbows) or mechanically (using foam rollers or pneumatic compression devices) is proposed to increase range of motion, skin and muscle temperature, venous, and arterial circulation. It is also proposed to reduce neuromuscular excitability, relieve cramps and pain and improve mood states [13]. In theory, all these effects may enhance postexercise recovery. Recent systematic reviews and meta-analyses indicate that massage after exercise reduces delayed onset muscle soreness [18^{*},26] and blood markers of muscle

damage and inflammation [18^{*}]. Massage also assists in reducing perceptions of fatigue [18^{*}], and restoring both maximal isometric force and peak torque after exercise [26]. More work is needed to determine the precise mechanism(s) of action that account for these effects, and the most appropriate type and timing of massage after exercise.

Hydrotherapy

Hydrotherapy encompasses four main strategies [69]: thermoneutral immersion (>20°C to <36°C), hot immersion ($\geq 36^\circ\text{C}$), cold immersion ($\leq 15^\circ\text{C}$), and contrast immersion (alternating between cold and hot water). The theoretical basis for using these various hydrotherapies to improve postexercise recovery is multifaceted, as described below:

- Cold immersion reduces body temperature, which may in turn alter the release of neurotransmitters that regulate fatigue, increase heat storage capacity and influence brain activity relating to alertness and arousal. Collectively, these responses may reduce the perception of fatigue [36^{*}].
- By reducing body temperature, cold immersion may reduce thermal demands on the body and stimulate vasoconstriction, resulting in less blood flow to the skin, increased central blood volume and lower cardiovascular strain [36^{*}].
- All forms of hydrotherapy exert hydrostatic pressure on the body, leading to fluid shifts. Combined with greater central blood volume, this may assist efflux of metabolites from skeletal muscle [36^{*}].
- Increased central blood volume may raise stroke volume, baroreceptor loading and parasympathetic activity, while simultaneously reducing sympathetic activity [36^{*}].
- The combination of vasoconstriction, reduced muscle temperature, increased central blood volume and analgesic effects of cold immersion may reduce inflammation, swelling and muscle soreness [36^{*}].

Compared with stretching and massage, research on hydrotherapy has adopted a more systematic approach by comparing physiological responses and performance effects after various types of exercise, water temperatures, durations and depths of immersion. Recent systematic reviews and meta-analyses have helped to clarify the effects of hydrotherapy.

Delayed onset muscle soreness

Cold and contrast immersion both reduce delayed onset muscle soreness after exercise, whereas hot water immersion is less effective [18^{*}]. Immersion in water at 11–15°C for 10–15 min is most effective for reducing muscle soreness [42]. There is no difference in muscle

soreness between immersing the whole body versus the legs only [18*].

Blood markers of muscle damage and inflammation

Cold and contrast immersion also reduce blood creatine kinase activity and interleukin-6 concentration after exercise, whereas hot immersion does not [18*].

Perception of fatigue

Cold immersion (but not contrast immersion) reduces perceptions of fatigue after exercise [18*]. The limited evidence available seems to indicate that perception of fatigue is lower after immersing the legs only versus the whole body [18*].

Body temperature

Pooled analysis from many studies has revealed that body temperature decreases by an average of 0.03°C for every 1°C decrease in water temperature. It also decreases by an average of 0.02°C for every additional minute of immersion [64]. The depth of cold immersion does not influence the rate of changes in body temperature after exercise [64].

Performance effects

Cold immersion provides the greatest benefit for recovery of sprint performance, and smaller benefits for recovery of endurance, jump performance and strength [55]. There are no clear differences between cold and contrast immersion regarding their effects on performance [31], but they both provide more consistent performance benefits compared with hot and thermoneutral immersion [69].

Individual considerations

Body composition influences the effects of cold immersion. Specifically, cold immersion reduces body temperature to a greater extent in individuals with low versus high body fat, whereas it only improves recovery of endurance performance in individuals with high body fat [63]. Because females have a lower thermolytic capacity than males, they may benefit more from cold immersion after exercise [29]. Regular cold immersion does not interfere with adaptations to endurance or high-intensity interval training, whereas it can attenuate adaptations to strength training [7*].

In summary, cold immersion (and perhaps to a lesser extent, contrast immersion) elicits various physiological responses that aid post-exercise recovery. More systematic research is needed to determine optimal hydrotherapy protocols after different modes of exercise.

Compression garments

Wearing compression garments to enhance postexercise recovery is a relatively recent, but very popular trend among athletes. Direct supporting evidence for the mechanisms of action of compression garments is

currently lacking. However, compression garments are proposed to enhance recovery from exercise by reducing dilation, venous stasis, and lymphoedema, and enhancing venous return, microcirculation, and elimination of metabolic waste products [14]. A recent systematic review and meta-analysis demonstrated that wearing compression garments after exercise reduces delayed onset muscle soreness and perception of fatigue [18*]. Wearing compression garments may also induce small improvements in biomechanical variables related to running economy (i.e. ground contact time, step frequency, step length, and swing time) [19], which may aid subsequent performance. The effects of wearing compression garments on blood markers of muscle damage and inflammation after exercise are more modest [18*]. The pressure exerted by compression garments appears to influence recovery of muscle function after exercise. Specifically, high-pressure compression garments that exert high compression restore muscle function more effectively compared with low-pressure compression garments [32]. In summary, wearing compression garments offer benefits for some aspects of recovery after exercise.

Cryotherapy

Similar to wearing compression garments, whole-body cryotherapy has gained interest in recent years as a postexercise recovery strategy. Cryotherapy involves briefly pulsing cold air or a refrigerated gas (usually CO₂) between -30°C and -140°C at a high intensity and pressure, in dry conditions, onto the skin over the muscles to be treated [17]. The theoretical basis for using cryotherapy is to reduce inflammation, reduce muscle tone to stimulate muscle relaxation, slow nerve conduction velocity to restrict pain, and induce vasomotor effects (alternating vasoconstriction and vasodilation) [17]. Less delayed onset muscle soreness after exercise is the most consistent benefit of cryotherapy [18*,33,40,58]. The effects of cryotherapy on blood markers of muscle damage and inflammation are more variable [18*,33,40,58]. Although a few studies have reported improvements in performance recovery after cryotherapy, variation in how performance was assessed precludes any definitive conclusions [58]. It is unclear whether cryotherapy provides greater benefits for recovery compared with other strategies such as cold immersion [1,73,74]. This is an important consideration for athletes, given the cost, infrastructure and maintenance required for cryotherapy.

Neuromuscular electrical stimulation

Neuromuscular electrical stimulation involves placing electrodes on the skin. This technique is intended to induce segmental sensory inhibition and endorphin release, stimulate blood flow, and reduce pain [13]. Various studies have investigated whether neuromuscular electrical stimulation influences different aspects of recovery after exercise. A systematic review indicated

that neuromuscular electrical stimulation is more effective than passive recovery (but not active recovery) for reducing delayed onset muscle soreness, perceived exertion and blood lactic acid concentration after exercise [44]. By contrast, this technique does not provide any clear benefit over either active or passive recovery for restoring muscle function and other aspects of performance after exercise [25,44].

Other physical interventions

Various other physical interventions including vibration therapy, dry-heat sauna, far-infrared sauna and laser/photo therapy have been tested as strategies for postexercise recovery. Vibration therapy can reduce delayed onset muscle soreness and blood creatine kinase activity, whereas it does not aid recovery of muscle strength after exercise [12,41]. Although there is anecdotal support among athletes for using sauna [28], research indicates limited benefits of this treatment for recovery from exercise [47]. Laser or photo therapy has gained interest in recent times. Most research has been conducted on animals, yet some evidence supports its use for individuals recovering after exercise [15,22]. Similarly, some animal research has reported benefits of hyperbaric oxygen therapy for recovery from muscle injury, but the effects of this treatment in humans are less clear [66].

Sleep

Sleep is recognized as a critical element of postexercise recovery. Much has been documented about the links between sleep and performance (physical and cognitive), the sleep habits of athletes, and the potential impediments to regular, healthy sleep routines for athletes [70]. Athletes may experience short-term sleep disturbance due to travel, jet lag, unfamiliar sleeping environments and pre-competition anxiety. They may also experience long-term sleep disturbance arising from poor sleep hygiene (e.g. late night games, use of technology before bedtime, unsuitable sleeping environments), chronic insomnia, and maladaptation to training load [6^{*}]. It is beyond the scope of this brief review to discuss the current literature on sleep and postexercise recovery in detail. Nevertheless, a few points are worth mentioning. By increasing total sleep duration for at least one week, sleep-deprived athletes can improve their physical performance, reaction times, mood and fatigue levels [6^{*}]. Napping for more than 20 min later in the day, and at a suitable interval after preceding exercise, may assist mental preparation for subsequent performance [6^{*}]. One-off sleep hygiene strategies can increase sleep duration, but they do not influence subsequent performance and recovery [6^{*}]. Ongoing education of athletes about good sleep hygiene may offer greater benefits for performance [6^{*}]. Strategies aimed at initiating sleep and an optimal physiological state for sleep may improve subjective and objective sleep patterns, but not necessarily performance [6^{*}]. When planning strategies to

Table 1

Key factors to consider when implementing postexercise recovery strategies

Performance effects Physiological effects	<ul style="list-style-type: none"> Some strategies induce effects on physiology and performance that could be ineffective (or even counterproductive) for restoring physiological function and aiding performance recovery.
Perceptual effects	<ul style="list-style-type: none"> Some strategies influence perceptions of fatigue, muscle soreness and body temperature, which could in turn influence motivation during subsequent training or competition.
Preceding exercise	<ul style="list-style-type: none"> The type of preceding exercise (i.e. intensity, duration, mode), and the associated physiological and environmental demands will dictate the most suitable strategies to use.
Frequency	<ul style="list-style-type: none"> Some strategies may be necessary after every training session (e.g. hydration), whereas others may only be required after some types of training sessions or competition.
Periodization	<ul style="list-style-type: none"> Some strategies may be more suitable during certain phases of the competitive season than others (e.g. during development versus maintenance phases).
Timing	<ul style="list-style-type: none"> There is often an optimal window of opportunity after exercise when (or when not to) use particular strategies to enhance (or not interfere with) specific aspects of recovery.
Specificity	<ul style="list-style-type: none"> The body mass, body composition, body surface area, age and sex of athletes will determine choice of strategies and how best to apply them.
Dose	<ul style="list-style-type: none"> The volume of fluids required and the amount of carbohydrate, protein and other nutritional compounds that athletes consume after exercise will depend on the preceding exercise and individual athlete characteristics such as body mass.
Intensity	<ul style="list-style-type: none"> The intensity of some strategies can be controlled, such as the depth of water immersion, pressure of massage and compression garments, voltage of neuromuscular electrical stimulation.
Duration	<ul style="list-style-type: none"> There may be an optimal duration to apply certain strategies, beyond which there are no additional benefits, or even negative effects.
Temperature	<ul style="list-style-type: none"> The temperature of water immersion, sauna, and cryotherapy chambers can be controlled, depending on individual requirements.

promote better sleep, it is important to recognize that sleep needs vary greatly between individuals. Individual motivation will also likely influence how well athletes adopt good sleep hygiene practices, and the most effective strategies remain unclear [6*].

Concluding remarks

Postexercise recovery is a cornerstone of successful athletic training programs. Well-designed recovery schedules are essential for reducing the risk of overreaching and maximizing adaptation. Table 1 outlines some important considerations when designing postexercise recovery programs. As a subdiscipline of exercise science, recovery science has grown and evolved substantially over the years. Future research in this field should be aimed at gaining a better understanding of the physiological basis for using various recovery interventions. Such endeavors will help to refine how such interventions are deployed. Much of the research to date has been conducted on relatively untrained individuals or recreational athletes exercising and undertaking recovery strategies in controlled laboratory settings. More research is needed on competitive athletes and the techniques they use to recover after training and competition. There has also been wide variation in exercise protocols used to induce fatigue and muscle damage, and the way that recovery strategies are implemented. Adopting more systematic comparisons of certain types of exercise and recovery interventions will also provide clearer guidelines to inform postexercise recovery practices. Most research has focused on single recovery interventions, yet there may be some additive benefits from combining different recovery techniques. Sleep is a large part of postexercise recovery, yet our understanding of why sleep is important and best practice for promoting good sleep behavior in athletes remains limited. Finally, it will be important for future research to establish when and how frequently to use recovery strategies without interfering with chronic training adaptations.

Conflict of interest statement

Nothing declared.

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