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Recovery interventions and strategies for improved tennis performance

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► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/bjsports-2013-093223>).

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Accepted 12 January 2014

ABSTRACT

Improving the recovery capabilities of the tennis athlete is receiving more emphasis in the research communities, and also by practitioners (coaches, physical trainers, tennis performance specialists, physical therapists, etc). The purpose of this article was to review areas of recovery to limit the severity of fatigue and/or speed recovery from fatigue. This review will cover four broad recovery techniques commonly used in tennis with the belief that the interventions may improve athlete recovery and therefore improve adaptation and future performance. The four areas covered are: (1) temperature-based interventions, (2) compressive clothing, (3) electronic interventions and (4) nutritional interventions.

INTRODUCTION

The emphasis on improving recovery in tennis athletes has gained more research interest over the past decade. It is gaining greater value with practitioners who work with tennis athletes (tennis coaches, certified tennis performance specialists, physical therapists, athletic trainers, strength and conditioning coaches, etc). The purpose of many different recovery techniques is to limit the severity of fatigue and/or speed recovery from fatigue. Fatigue is the consequence of 'overloading' stress^{1 2} placed on physiological systems and is reflective of the conditions or demands of a given activity, which in turn dictates the recovery that is needed. The challenge from a physiological standpoint is that different types of training induce different types of fatigue. When power output cannot be maintained or homeostasis cannot be achieved in a given set of physiological systems, fatigue occurs.¹ A host of physiological mechanisms including central and peripheral factors are believed to contribute to fatigue.^{3–8} Tennis players have been shown to suffer stroke accuracy decrement as high as 81% with increasing play durations.⁹ Fernandez *et al*¹⁰ have suggested playing style, gender, training status, playing surface, ball type and environment as the primary contributors to fatigue in tennis. The varied causes of fatigue make it difficult to determine the best recovery modalities for the tennis athlete. As recovery is such a broad topic, it is not feasible in this review to cover all the techniques that are used to help tennis athletes recover from strenuous physical training or competition. However, this review will cover four areas of recovery techniques commonly used in tennis with the belief that the interventions may improve athlete recovery and, therefore, improve adaptation and future performance. The four areas covered are: (1) temperature-based interventions, (2) compressive clothing, (3) electronic interventions and (4) nutritional interventions.

TEMPERATURE-BASED INTERVENTIONS

Hydrotherapies have been in use for several thousand years. Spas, pools, steam rooms, cold pools and contrast temperature protocols were used by the ancient Greeks and Romans.¹¹ Below are the most common temperature-based recovery techniques currently being implemented with tennis athletes.

Cooling

Cooling has been suggested to have a number of effects, including decreased muscle temperature, muscle damage and postexercise inflammation,¹² reduced heart rate and cardiac output,¹³ peripheral vasoconstriction and reduced peripheral oedema formation^{12–14} and analgesic effects.¹⁵ The actual mechanisms underlying the potential benefits of cooling interventions are still unclear.¹⁶ The effects of cooling on recovery have been reported to be larger for weight-bearing sports (ie, eccentric exercise) than for non-weight-bearing sports (cycling, swimming).¹⁷ Although no gold standard temperature protocol has been established, a typical recommendation by multiple researchers and practitioners is to cool the water to 10–15°C.^{17 18} In a meta-analysis of 21 studies (using a range of 5–15°C), the average improvement in performance measures (endurance, strength, sprint and jump activities) were 2–3%.¹⁹ A 2–3% improvement in tennis performance can significantly aid an athlete during a tournament, but also can help in the day-to-day improvements during practice. The higher the level of competition, the more important this small improvement becomes. Although many different cooling methods exist, the best outcomes have been found with cold water immersion techniques (typically between 5°C and 15°C¹⁹) over other forms of cooling (ice packs, ice vests, ice towels, etc).¹⁹ Immersion is a highly efficient method of cooling and decreases body core temperature at a rate of 0.15–0.35°C/min.^{20 21}

In addition to temperature changes in muscle, another mechanism to explain the possible benefit of cooling on postexercise recovery is the effect of hydrostatic pressure.²² Hydrostatic pressure increases cutaneous interstitial pressure, causing a fluid shift from the interstitial to the intravascular space,²³ which may reduce oedema and possibly secondary tissue damage.²² This process also increases intracellular–intravascular osmotic gradients, enhancing the clearance of waste products and possibly improving muscle contractile function.^{24 25} The increase in hydrostatic pressure results in a rise of central blood volume and cardiac output,²⁶ increasing blood flow and the clearance of waste products. It is interesting to note that these responses increase as the depth of



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To cite: Kovacs MS, Baker LB. *Br J Sports Med* 2014;**48**:i18–i21.

water immersion increases.²² Cooling packs or cooling vests have not shown benefits for recovery parameters, possibly because the body area cooled was too small to elicit hydrostatic pressure changes.¹⁹

A rather new whole body cooling technique, called a cryogenic chamber, is becoming more popular as a recovery tool for competitive athletes. Studies have investigated the influence of two sets of 3 min in a cryochamber (-110°C) at 24 and 26 h postexercise²⁷ or three sets of 3 min in a cryochamber (-110°C) immediately postexercise and 24 and 48 h postexercise.²⁸ These two studies showed vast differences in recovery measures. Cryotherapy performed 24 h after exercise was ineffective in alleviating muscle soreness or enhancing muscle force recovery,²⁷ whereas when cryotherapy was started immediately postexercise²⁸ improvements were found. The delay in cryotherapy by 24 h may have reduced the ability to improve recovery metrics. Although limited studies currently exist on cryotherapy chambers, and significantly more research is needed in this area, the use of -110°C chambers in short durations (~ 3 min) immediately postexercise may have some positive effects on recovery.¹⁹ In an interesting study in tennis using this modality, 5 days of whole-body cryotherapy chamber exposure in conjunction with moderate-intensity training considerably improved the blood cytokine profile and physical performance of professional tennis players (ATP ranked between 150 and 900).²⁹ However, cryotherapy chambers are significantly more costly than cold water immersion treatments and more data comparing the two methods are needed to determine if any greater benefits in recovery may be achieved.

Timing

Tennis requires athletes to perform multiple matches or practices in a single day. Some research has investigated the influence of cooling techniques used between these types of activities. If recovery time is less than 60 min the benefits of cooling techniques are suggested to be less about recovery and more related to precooling for the next exercise bout.¹⁷ When 2–3 h of recovery time is allowed between exercise bouts only negligible effects of cooling on performance have been found. It is interesting to note that cold water immersion techniques may be more effective the longer the timeframe between bouts. In a meta-analysis,³⁰ the authors concluded that the largest effects of cooling on recovery can be expected 2–4 days after exercise.¹⁹ Effects of cooling were larger when repeatedly applied (usually once per day), so from a practical perspective, it has been suggested that cooling should take place immediately after exercise, and also on a daily basis following strenuous exercise.¹⁷

Hot water immersion

Throughout history, warm and hot water treatments have been used for muscle relaxation after physical exertion. Immersion of the body in 34 – 36°C water results in marked changes in the circulatory, pulmonary, renal and musculoskeletal systems as a result of increased hydrostatic pressures.^{11 22} The effects have been shown to be most pronounced for whole body (head out) immersion rather than partial immersion as increased pressure is proportional to the size of the immersed body surface area parts. Some studies have attempted to evaluate the influence of warm or hot water immersion of whole body^{24 31} or legs only³² on postexercise recovery. The legs-only immersion study found negligible effects on recovery parameters and were inferior compared with whole body immersion. Although hot water immersion showed benefits for whole body immersion, these benefits were inferior for recovery compared with cold water immersion.

Alternating from cool to warm water immersion can accelerate clearance of blood lactate^{33 34} and creatine kinase.³⁵

COMPRESSIVE CLOTHING

In recent years, compressive clothing have become fashionable with athletes in the hopes of reducing injuries, benefiting performance and enhancing recovery.^{36–38} Cycling performance has been shown to improve after wearing compressive clothing during recovery; however, effects on oxygen cost and RPE were unclear.³⁶ The recovery benefits reported from the use of compressive clothing are similar to those reported for hydrotherapy, as hydrostatic pressures perform a similar role in both methods. These benefits stem from the graduated pressures which extend medially from limb extremities towards the body core. Studies indicate that the sports compression garments reduce postexercise oedema following eccentric work and reduce sensations of ensuing muscle soreness,³⁹ as well as aid recovery of soft tissue injuries.³⁹ Furthermore, reduced perception of fatigue^{25 37} and enhanced clearance of blood lactate and creatine kinase have been reported with compression garments compared with passive recovery.^{35 37} Although perceptions of fatigue is an important variable for athletes, limitations do exist using this measure in studies due to difficulty of blinding participants to whether they have received treatment (compressive clothing) versus passive recovery.

Although compressive clothing seems to have some favourable effects on recovery and subsequent performance, limited practical recommendations can be made at this time due to a number of factors,⁴⁰ and limited research is currently available specifically in tennis. Also, more work is needed in comparing how compression of different limbs (ie, lower limbs vs upper limbs) may influence a tennis athlete's recovery. However, a combination of hydrotherapy techniques followed by the use of compressive garments appear to be beneficial for players between matches and post-training/event, whereas either strategy on its own is less effective.⁴¹ This notion was supported in a recent tennis-specific study that showed improved overall recovery in a number of factors if a combination of cold therapies, compression clothing and improved sleep hygiene was implemented. The study found improvements in time in play (approximately 10% increase in playing time), *a large effect size ($d > 0.90$) compared with control in lower body power (as measured via a counter-movement jump)*, and reduced perceived soreness.⁴²

ELECTRONIC TECHNIQUES

Although many types of electrical stimulation techniques exist, the focus of this section will be on non-invasive techniques. The electrical stimulation reviewed involves a series of stimuli delivered superficially using electrodes placed on the skin. When reviewing the literature in this area, it is clear that very little consistency exists. The different stimulation forms include microcurrent electrical neuromuscular stimulation,⁴³ high-volt pulsed current electrical stimulation,⁴⁴ monophasic high-voltage stimulation⁴⁵ and the most frequently used transcutaneous electrical nerve stimulation,⁴⁶ while still other stimulation forms fall under the category of low-frequency electrical stimulation (see figure 1 and table 1). When discussing electrical stimulation, there are two major effects related to postexercise recovery. First, there is an increase in muscle blood flow which helps accelerate muscle metabolite removal. For this purpose, the electrodes are placed over the muscle motor points.⁴⁷ Second, electrical stimulation reduces muscle pain through the stimulation of analgesic effect. For this purpose, the electrodes

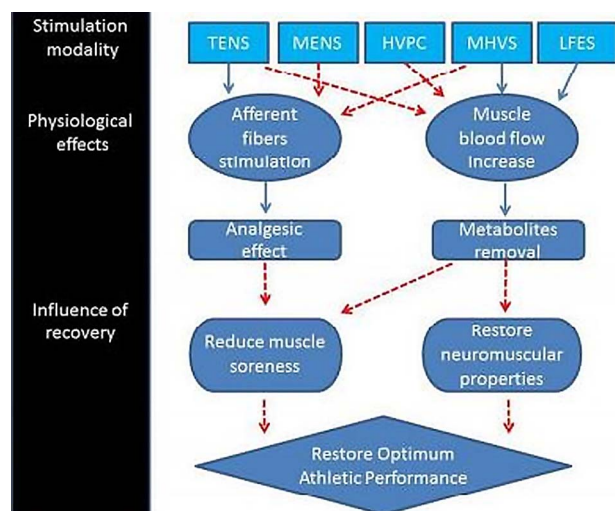


Figure 1 Diagram of known (solid line) and expected (dashed line) effects of different electrical stimulation forms used for postexercise recovery. TENS, transcutaneous electrical nerve stimulation; MENS, microcurrent electrical neuromuscular stimulation; HVPC, high-volt pulsed current; MHVS, monophasic high-voltage stimulation; LFES, low-frequency electrical stimulation. Diagram adapted from Babault *et al.*⁴⁹

are either placed on the injured site⁴⁴ or possibly away from it (ie, acupoints).⁴⁸

Irrespective of the muscular action mode, muscle group and stimulation parameters, electrical stimulation applied for recovery has been shown to be ineffective regarding torque production capacity and neuromuscular parameters.⁴⁹ No obvious benefits have been seen with improvement in vertical jump or sprint performance⁵⁰ or aerobic performance such as oxygen consumption.⁵¹ It appears that electrical stimulation may have

Table 1 Examples of electrical stimulation characteristics used for recovery

Name	Current characteristics	Electrode placement
MENS		
Microcurrent electrical neuromuscular stimulation	10 min at 30 Hz+10 min at 0.3 Hz	Muscle belly
HVPC		
High-volt pulsed current	30 min at 120 Hz (impulse duration=40 μ s)	Site of pain
TENS		
Low-frequency transcutaneous electrical nerve stimulation	20 min at 4 Hz (impulse duration=200 μ s)	Site of pain
TENS		
High-frequency transcutaneous electrical nerve stimulation	20 min at 110 Hz (impulse duration=200 μ s)	Site of pain
MHVS		
Monophasic high-voltage stimulation	30 min at 120 Hz (impulse duration=100 μ s)	Muscle belly
LFES		
Low-frequency electrical stimulation	20 min at 5 Hz (impulse duration=250 μ s)	Muscle motor point

Adapted from Babault *et al.*⁴⁹

HVPC, high-volt pulsed current; LFES, low-frequency electrical stimulation; MENS, microcurrent electrical neuromuscular stimulation; MHVS, monophasic high-voltage stimulation; TENS, transcutaneous electrical nerve stimulation.

some positive effects on improving the removal of metabolites such as lactate.⁵² However, no studies have reported any short-term effects of muscle recovery acceleration on neuromuscular, anaerobic and aerobic variables.⁴⁹ When used as a recovery modality, electrical stimulation demonstrated some positive effects on creatine kinase activity but evidence regarding performance indicators restoration, such as muscle strength, is still lacking.⁴⁹ Although some forms of electrical stimulation show some potential positives for athlete recovery, more research is needed in general, but specifically, with tennis athletes.

NUTRITIONAL ASPECTS OF TENNIS RECOVERY

The main components of nutrition-related recovery covered below include water and electrolyte intake for rehydration, restoration of carbohydrate stores and protein ingestion for muscle recovery. However, because little tennis-specific information is available, the recommendations are largely extrapolated from studies with endurance and/or strength-trained athletes.

Rehydration

During tennis play, metabolic heat production from exercise and heat gain from the environment cause an increase in body core temperature. Consequently, fluid loss through sweating occurs to dissipate body heat and regulate core temperature. Sweating rates in tennis players have been reported to range from less than 0.5 to over 2.5 L/h.⁵³⁻⁵⁴ The composition of sweat includes electrolytes, particularly sodium, which ranges from approximately 20–80 mEq/L of sweat.⁵³ The wide range in sweating rates and sweat sodium concentration among players is due to differences in genetics, maturation, body size, training/match intensity, environmental conditions and/or heat acclimatisation status. When fluid intake is less than sweat loss, a body water deficit, or dehydration, occurs. There is a paucity of data regarding the effect of hypohydration on tennis-specific performance. However, hypohydration has been found to impair aerobic performance, postural balance,⁵⁵ cognitive performance, mood and mental readiness,⁵⁶⁻⁵⁷ which are all important components of tennis performance. Although some individuals may be more or less sensitive to hypohydration, the level needed to induce performance degradations approximates >2% decrease in body mass.⁵⁶⁻⁵⁷ There is also evidence that further body water deficits result in further deteriorations in sport/exercise performance.⁵⁶⁻⁵⁸⁻⁵⁹ Competitive tennis is typically played in warm-hot environments. Thus, it is important to note that the detrimental effect of hypohydration on aerobic performance is exacerbated when combined with heat stress.⁵⁶ Furthermore, hypohydration impairs the body's heat dissipating mechanisms (ie, skin blood flow and sweating), leading to increased core temperature and risk of heat illness.⁵⁶ Therefore, fluid replacement to ameliorate the deterioration in physiological function and performance that accompanies hypohydration is an important aspect of recovery from tennis play.

It is critical that fluid intake is customised for each individual's hydration needs. Body mass assessments can be used to gauge a player's sweat loss following a workout. Acute body mass change (eg, from before to after <3 h training) represents approximately 1 L of water loss per 1 kg of body mass loss.⁶⁰ To achieve rapid and complete rehydration, it has been recommended for athletes to drink ~1–1.5 L of a sodium-containing (20–50 mEq/L) fluid for each kg of body mass lost.⁵⁶⁻⁵⁷⁻⁶¹ The ingestion of sodium with a fluid replacement beverage helps stimulate more complete rehydration, including better plasma volume restoration and whole body fluid balance compared with ingestion of plain water.⁶²⁻⁶⁵ The increase in serum

sodium concentration and osmolality with sodium ingestion stimulates renal water reabsorption, as urine output is inversely related to the sodium content of the ingested fluid.⁶³ Providing a chilled beverage with the addition of flavour and sweetness can improve beverage palatability and voluntary fluid intake.⁵⁶

Carbohydrate

Owing to the stop-and-go nature of the sport, tennis players use a combination of anaerobic and aerobic energy systems, both of which rely on carbohydrate as the primary fuel source. Tennis practices/matches, especially those of longer duration and intensity, likely decrease glycogen stores. Therefore, carbohydrate intake to replenish liver and muscle glycogen before the next training session/match is an important aspect of recovery for the tennis player.⁶⁶

The recommendations for carbohydrate intake during recovery are dependent on training/competition demands. When there is less than 8 h of recovery between practices or matches, experts recommend 1.0–1.2 g carbohydrate/kg immediately after the first session. This carbohydrate intake rate should be repeated every hour for 4 h.^{67 68} The timing of carbohydrate intake is especially important if the athlete has two practices or matches in 1 day. However, if there are one or more days between intense training sessions, the timing for glycogen replenishment is less urgent, provided sufficient carbohydrates are consumed during 24 h after the practice or match.⁶⁹ Daily needs for carbohydrate fuel to support recovery and replenish muscle and liver glycogen stores (ie, in 24 h between tennis play) is 5–7 g carbohydrate/kg/day for moderate training (~1 h/day) or 6–10 g carbohydrate/kg/day for moderate-to-high-intensity periods of training (1–3 h/day).⁶⁷ It is important to note that these carbohydrate recommendations are largely extrapolated from endurance exercise studies. However, the same intake recommendations have also been advocated for stop-and-go sports such as tennis.^{66 68 70 71}

The type of recovery food/snack consumed during short recovery periods should be easily digested carbohydrate sources.⁷⁰ Players should avoid foods that are high in fat, protein and fibre to reduce the risk of gastrointestinal issues during a subsequent event.⁶⁷ As there can be interindividual differences in gastrointestinal tolerance to certain foods and fluids, players should also take into consideration their individual preferences and previous experiences when selecting the timing, amount and source of carbohydrate to consume.

Protein

Another important nutritional aspect of recovery from tennis play is the ingestion of protein to promote resynthesis of muscle protein and aid in the muscle recovery process. Limited information is available on the postexercise protein needs of tennis players, thus recommendations are largely extrapolated from those targeted towards strength-trained and endurance athletes. The consumption of 20–25 g of protein after exercise is recommended in order to stimulate muscle protein synthesis and possibly lower the rate of muscle protein breakdown.⁷² Higher rates of protein intake after exercise have not been shown to confer additional benefits.⁷² The type and timing of protein ingestion are important considerations. A high-quality protein that provides all of the essential amino acids (leucine in particular) is needed for the adaptation to occur.⁷² The recommended timing for protein ingestion is as soon as possible after exercise, particularly if optimum muscle adaptation and performance are a high priority. To meet daily protein requirements (ie, in 24 h between sessions), it has been recommended that the tennis

athlete training at a high intensity and duration on a daily basis consume ~1.6 g protein/kg/day.⁶⁶ This is similar to the 1.2–1.7 g protein/kg/day recommended for endurance and resistance-trained athletes.⁷³

It is important to reiterate that tennis coaches and players should take into consideration the individual needs and preferences of the athlete. The nutrition recommendations outlined above are largely extrapolated from endurance-type activity conducted with college-aged individuals. Tennis competition is not only unique in its stop-and-go nature but also in its relatively brief opportunity for nutritional recovery between matches during tournament play. Rapid recovery is especially critical in this situation, thus more tennis-specific research is needed.

CONCLUSIONS

Tennis athletes' postexercise recovery is a growing multifaceted area that involves many different techniques to help speed recovery from fatigue. This review highlighted some of the most commonly used techniques in the field. Although much more research is needed in tennis, some broad generalisations can be made from the information reviewed. The use of cold treatments has been shown to be superior for recovery compared with warm/hot water immersion. Compressive clothing used during recovery from tennis play shows positive results and appears to be a cost-effective method to aid recovery, especially when combined with hydrostatic techniques. The literature on the different forms of electrical stimulation are mixed, and although some forms of electrical stimulation show some potential positives for athlete recovery, more research is needed. Replacement of fluid and electrolyte losses, restoration of carbohydrate stores and protein intake are important nutritional aspects of recovery from exercise. However, more work is needed to determine the optimal amount and timing of fluid, carbohydrate and protein intake for postexercise recovery in tennis players at different maturational stages, especially in the face of physiological and practical challenges related to tournament play.

Contributors MSK planned the review and wrote a substantial portion of the manuscript. LBB contributed a substantial portion to the review by researching and writing multiple sections of the manuscript.

Competing interests MSK and LBB are employees of the Gatorade Sports Science Institute, a division of PepsiCo, Inc.

Provenance and peer review Commissioned; externally peer reviewed.

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Br J Sports Med 2014 48: i18-i21

doi: 10.1136/bjsports-2013-093223

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