



RECOVERY TECHNIQUES FOR ATHLETES

Shona L. Halson | Recovery Center | Australian Institute of Sport | Canberra | Australia

KEY POINTS

- Recovery is becoming increasingly important to the high-performing athlete in a bid to reduce fatigue and enhance performance.
- Some of the more common recovery techniques utilised by athletes include hydrotherapy, active recovery, stretching, compression garments and massage.
- In the previous 5-10 years, there has been a significant increase in research examining both the effects of recovery on performance and potential mechanisms.
- Recent research suggests that hydrotherapy, compression and massage can enhance acute performance when utilised appropriately.
- As recovery is a relatively new area of scientific research, athletes are encouraged to experiment with various recovery techniques to identify useful individualized recovery strategies.

INTRODUCTION

Professionalism in sport has provided the foundation for elite athletes to focus purely on training and competition. Furthermore, high-performance sport and the importance of successful performances have led athletes and coaches to continually seek any advantage that may improve performance. It follows that the rate and quality of recovery are extremely important for the high-performance athlete and that optimal recovery may provide numerous benefits during repetitive high-level training and competition. Therefore, investigating different recovery interventions and their effects on fatigue, muscle injury, recovery and performance is important.

Adequate recovery has been shown to result in the restoration of physiological and psychological processes, so that the athlete can compete or train again at an appropriate level. Recovery from training and competition is complex and typically dependent on the nature of the exercise performed and any other outside stressors. Athletic performance is affected by numerous aspects and therefore, adequate recovery should also consider such factors (See Table 1).

RESEARCH REVIEW

Methods to Enhance Recovery

There are a number of popular methods used by athletes to enhance recovery. Their use will depend on the type of activity performed, the time until the next training session or event and equipment and/or personnel available. Some of the most popular recovery techniques for athletes include hydrotherapy, active recovery, stretching, compression garments, massage, sleep and nutrition. (Note: Both “Sleep and the Elite Athlete” and “Nutritional Interventions to Enhance Sleep” have been addressed in other Sports Science Exchange articles and therefore, will not be covered here.)

TRAINING/COMPETITION	Volume, intensity, duration, type of training/sport, degree of fatigue, recovery from previous training/competition
NUTRITION	Carbohydrate, protein and other nutrient intake, fluid and electrolyte balance
PSYCHOLOGICAL STRESS	Stress and anxiety from competition
LIFESTYLE	Quality and amount of sleep, schedule, housing situation, leisure/social activities, relationship with team members, coach, friends and family, job or schooling situation
HEALTH	Illnesses, infection, injury, muscle soreness and damage
ENVIRONMENT	Temperature, humidity, altitude

Table 1. Factors affecting athletic performance

Hydrotherapy

Although hydrotherapy is incorporated widely into post-exercise recovery regimes, information regarding these interventions is largely anecdotal. The human body responds to water immersion with changes in the heart, peripheral resistance and blood flow, as well as alterations in skin, core and muscle temperature (Wilcock et al., 2006). The changes in blood flow and temperature may have an effect on inflammation, immune function, muscle soreness and perception of fatigue.

Endurance Exercise

Various forms of water immersion recovery techniques are becoming increasingly popular with elite athletes. While athletes have been using hydrotherapy for a number of years, research into the potential recovery effects of water immersion, recovery and performance are now appearing. The most common forms of water immersion are cold water immersion (CWI), hot water immersion (HWI) and contrast water therapy (CWT), where the athlete alternates between hot and cold water immersion.

Coffey et al. (2004) investigated the effects of three recovery interventions (active, low-intensity exercise; passive, seated rest; and CWT) on repeated treadmill running performance separated by 4 h. Contrast water therapy was associated with a perception of improved 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. Hamlin (2007) also found CWT to have no beneficial effect on performance during repeated sprinting. Twenty rugby players performed two repeated sprint tests separated by 1 h and completed either CWT or active recovery between trials. An active recovery generally consists of aerobic exercise that can be performed using different modes such as cycling, jogging, aqua jogging or swimming. Active recovery is often thought to be better for recovery than passive recovery due to enhanced blood flow to the exercised area and clearance of lactate and other metabolic waste products via increased oxygen delivery and oxidation.

Even though substantial decreases in blood lactate concentration and heart rate were observed following CWT when compared to active recovery, performance in the second exercise bout was decreased compared with the first exercise bout regardless of the intervention.

In a study investigating the dose-response effect of CWT, the authors reported substantially improved cycling time trial and sprint performance following 6 min of CWT (hot water: 38.4°C; cold water: 14.6°C; 1 min rotations) when compared to control (passive rest) (Versey et al., 2011a). The time between cycling bouts was 2 h and the duration of each cycling bout was 75 min. However, there was no improvement in repeat performance with 18 min of CWT, indicating that a dose-response relationship does not exist under these conditions. Twelve minutes of CWI also improved sprint total work and peak power. 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) (Versey et al., 2011b). However, in this instance, the first bout consisted of a 3,000 m time trial and 8 x 400 m intervals. The second bout of exercise was a 3,000 m time trial. The results of this study again demonstrated that CWT for 6 min improved performance, whereas 12 and 18 min did not, indicating the lack of a dose-response relationship between running performance and CWT. Importantly, this study was performed outdoors at 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.

The effectiveness of CWI and CWT on recovery from simulated team sport performance (running) was assessed across a 48 h period (Ingram et al., 2009). Each subject completed three testing trials lasting 3 d with CWI, CWT or passive recovery completed immediately after the initial exercise bout and again at 24 h after exercise. Performance (time taken to complete 10 x 20 m sprints and leg extension/flexion isometric force) was assessed before exercise and 48 h after exercise. Cold water immersion (2 x 5 min in 10°C) was significantly better than both CWT (2 min cold in 10°C, 2 min in 40°C x 3) and passive recovery in reducing ratings of muscle soreness, and reducing decrements in isometric leg extension, flexion force and sprint performance from baseline value. Contrast water therapy also improved muscle soreness at 24 h when compared with passive recovery.

The effects of three hydrotherapy interventions on next day performance recovery following strenuous training was investigated on 12 male cyclists, who completed four experimental trials differing only in recovery intervention: CWI, HWI, CWT or passive recovery (Vaile et al., 2008b). Each trial consisted of five consecutive exercise days (105 min duration, including 66 maximal effort sprints) followed by recovery on each day. After completing each exercise session, participants performed one of the four recovery interventions in a randomised crossover design. Sprint (0.1–2.2%) and time trial (0.0–1.7%) performance were enhanced across the 5 d trial following both CWI and CWT when compared to HWI and passive recovery (Vaile et al., 2008b).

Vaile et al. (2008a) also examined different water immersion temperatures (15 min of intermittent immersion in 10° C, 15° C, 20° C, continuous immersion in 20° C water, 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. Each trial was separated by seven days. All water immersion protocols significantly improved subsequent cycling performance when compared to active recovery.

From the above information, it appears that hydrotherapy may be beneficial for endurance-trained athletes, particularly those performing high-intensity efforts. Specifically, CWI and CWT appear more beneficial than HWI for recovery from endurance exercise.

Team Sports

Rowell et al. (2009) conducted a 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 to thermoneutral water immersion (control condition) on indicators of soccer performance. However, the perception of fatigue and muscle soreness was lower in the cold water immersion group.

In rugby players, researchers have reported that CWT had no beneficial effect on performance during repeated sprinting (Hamlin, 2007). Twenty participants performed two repeated sprint tests separated by 1 h. They completed either CWT or active recovery between trials. While substantial decreases in blood lactate concentration and heart rate were observed following CWT compared to the first exercise bout, performance in the second exercise bout was decreased similarly regardless of the intervention (Hamlin, 2007).

When examining the effect of various recovery strategies (passive, active, CWI, CWT), King and Duffield (2009) reported no significant effects of any of the 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 a smaller decline in sprint performance and vertical jumps with both CWT and CWI. The time frame between testing sessions was 24 h, suggesting that complete recovery may have occurred prior to repeat testing. It is possible that the water immersion protocols were not substantial enough to have an effect, with immersion to the iliac crest only and showers used for the hot water exposure in the CWT. This finding may suggest that muscle temperature is a key factor when considering the timing of recovery strategies.

The effectiveness of three recovery strategies (carbohydrate intake and stretching, CWI and full leg compression garments) was examined before and after a 3 d basketball tournament in state-level athletes (Montgomery et al., 2008). Recovery was performed each day and the athletes played one full 48 min game per day. Sprint, vertical jump, line-drill performance and agility performance and 20 m acceleration decreased across the 3 d tournament, indicating accumulated fatigue. CWI was substantially better than other strategies in maintaining 20 m acceleration. CWI and compression showed similar benefits in maintaining line-drill performance when compared to carbohydrate and stretching.

It should be noted that in well-controlled laboratory studies that have examined the effects of recovery on performance, positive effects of various forms of hydrotherapy have been demonstrated (as mentioned previously in the Endurance Exercise section). However, limited studies utilising team sports scenarios combined with large differences in methodology have resulted in less clear findings in team sport athletes when compared to previous laboratory research.

For thorough reviews of CWT and CWI, please see these recent review articles (Halson, 2011; Leeder et al., 2012; Versey et al., 2013).

Active Recovery

It is not clear whether there are benefits of an active recovery between training sessions or following competition in various sports. No detrimental effects on performance have been reported following an active recovery (when compared to a passive recovery) between training sessions, along with a small amount of literature reporting enhanced performance. Many researchers, however, use the removal of lactate as their primary indicator of recovery and this may not be a valid indicator of enhanced recovery and the ability to repeat performance at a previous level (Bond et al., 1991).

A recent study investigated the effects of a swim recovery session on subsequent running performance and reported an increase in performance when compared to passive recovery (Lum et al., 2010). Well-trained triathletes completed a high-intensity running session followed 10 h later by either a swim session (20 x 100 m at 90% of 1 km time trial speed) or passive recovery. Twenty-four hours following the initial running session, a time to fatigue run test was performed. The swim trial resulted in subjects running for 830 + 98 s, compared to the passive trial in which subjects ran for 728 + 183 s. This improvement may have been due to the hydrostatic benefits of water (thought to increase venous return and blood flow) and/or the active recovery per se.

The influence of the intensity of active recovery on the clearance of blood lactate has also been investigated (Menziés et al., 2010). Different running intensities during active recovery were compared to passive recovery and it was reported that lactate was lower following higher intensities (60-100% of lactate threshold) than lower intensities (0-40% of lactate threshold). Maximum lactate clearance occurred during active recovery at intensities close to lactate threshold. It should be noted that maximal lactate concentrations were low (3.9 mM) in this study and subjects were only moderately trained. Carter et al. (2002) investigated the effects of mode of exercise recovery on thermoregulatory and cardiovascular responses, with the data suggesting that mild active recovery may play an important role for post-exertional heat dissipation. However, the mechanism(s) behind these altered responses during active recovery is unknown.

The role of active recovery in reducing lactate concentrations after exercise may be an important factor for athletes, although the research in this area is incomplete. This is anecdotally reported to be one of the most common forms of recovery and utilised by the majority of athletes for these reasons.

Stretching

Although stretching is anecdotally one of the most used recovery strategies, the literature examining the effects of stretching as a recovery method is sparse. In team sport athletes, Kinugasa and Kilding, (2009) assessed the effects of 7 min of static stretching following a football game. Stretching was not as effective as CWT or a combined recovery (CWT and active recovery) for improving the subject's perceived recovery. Similarly, Montgomery et al. (2008) reported that a combined recovery strategy (stretching and carbohydrate intake) performed immediately after three basketball games over 3 d was not as effective as CWI for restoring physical performance (20 m sprint, basketball specific running drill, sit and reach test).

In contrast, Dawson and colleagues (2005) reported that stretching following an Australian football match significantly improved power output during a 6 s cycle sprint 15 h after the match, compared to a control. Additionally, Miladi and colleagues (2011) reported that dynamic stretching was significantly superior to active or passive recovery for maintaining a second bout of cycling to exhaustion. Finally, following a muscle damaging protocol, stretching was found to improve range of motion and reduce muscle soreness compared to a control (Kokkinidis et al., 1998).

As can be concluded from the above findings, there have been mixed reports regarding the benefit of stretching as a recovery strategy. However, two separate reviews of recovery methods concluded that there was no benefit for stretching as a recovery modality (Barnett, 2006; Vaile et al., 2010). It is important to note that to date, there have not been any detrimental effects on performance associated with post-exercise stretching.

Compression Garments

Many recovery strategies for elite athletes are based on medical equipment or therapies used in patient populations. Compression clothing is one of these strategies that has been traditionally used to treat various lymphatic and circulatory conditions. Compression garments are thought to improve venous return through application of graduated compression to the limbs from proximal to distal (Bochmann et al., 2005). The external pressure created may reduce the intramuscular space available for swelling and promote stable alignment of muscle fibres, attenuating the inflammatory response and reducing muscle soreness (Kraemer et al., 2001).

Recreational runners wearing compression garments have been examined during and after intermittent and continuous running (Ali et al., 2007). The authors found that there was a reduction in delayed onset muscle soreness 24 h after wearing compression garments during a continuous exercise task (10 km). While not statistically significant, there was a trend for participants in the compression trial to perform the 10 km in a faster time than when not wearing the compression garments. Subjects wore commercially available graduated compression stockings, with the compression highest

at the ankle (18-22 mmHg) and reduced by 70% to the top of the stocking, which ended below the knee. Recently, a reduction in the perception of muscle soreness after wearing compression garments during sprinting and bounding exercise and for 24 h after exercise was reported (Duffield et al, 2010). While perceptions of soreness were reduced, there was no change in sprint performance while wearing the garments.

While there is currently minimal research into compression garments and recovery for endurance athletes, the small amount of data suggests that there may be some small benefits and there is no indication that they impede the recovery process (Hill et al., 2013).

Massage

Massage is a widely used recovery strategy among athletes. However, apart from perceived benefits of massage on muscle soreness, few reports have demonstrated positive effects on repeated exercise performance. Furthermore, increased blood flow is one of the main mechanisms proposed to improve recovery (thus improving clearance of metabolic waste products). However, many studies reported no increase in blood flow or lactate removal during massage (Monedero & Donne, 2000, Tiidus & Shoemaker, 1995). Indeed, in a recent study, Wiltshire and colleagues (2010) reported that massage actually impaired blood flow and lactate removal.

Lane and Wenger (2004) reported that massage was superior to passive recovery in maintaining cycle performance separated by 24 h. However, active recovery and cold water immersion provided greater (non-significant) benefits compared to massage. Monedero and Donne (2000) reported that massage was no more effective than passive recovery performed between two simulated 5 km cycle time trials separated by 20 min. However, a combined recovery consisting of active cycling and massage was significantly superior at maintaining performance than active cycling or massage in isolation, or passive recovery. In contrast, in high-intensity cycle sprints (8 x 5 sec sprints repeated twice), Ogai and colleagues (2008) reported that when massage was performed between the two bouts, total power output of the second bout was enhanced compared to the control. It should be noted that no other recovery strategies were performed, and as such, it is difficult to make recommendations for massage over other forms of recovery.

Several reviews of the effects of massage have concluded that while massage is beneficial in improving psychological aspects of recovery, most evidence does not support massage as a modality to improve recovery of functional performance (Barnett, 2006; Weerapong et al., 2005). However, as massage may have potential benefits for injury prevention and management; massage should still be incorporated in an athlete's training program for reasons other than recovery.

Practical Applications

While there are not a large number of scientific studies investigating recovery strategies in athletes, current evidence as well as anecdotal evidence from athletes suggests that completing appropriate recovery can aid in enhancing performance. At present, the following general recommendations can be made (Halson, 2011):

- Consideration should be given to the amount of time until the next training session or competition. Is a recovery procedure necessary? What can be practically performed in the time frame? What strategies have scientific evidence to support their use in the given time?
- Use appropriate temperatures and duration for water immersion. Research has found positive effects of water immersion at temperatures of 10–15°C for cold water and 38–40°C for hot water.
- Cold water immersion or contrast water therapy for a duration of 14–15 min has been shown to improve performance in selected studies.
- The ratio of hot-cold water immersion during contrast-water therapy should be 1:1. Research that has reported positive performance effects used seven rotations of 1 min hot and 1 min cold.
- Compression garments and active recovery may be beneficial for recovery in endurance-trained athletes. While the positive evidence is minimal at present, there does not appear to be harmful effects relating to their use, and anecdotal evidence for their support is high. Further well-controlled research is needed.

Summary

As recovery research is a relatively new area for scientists, many of the current recommendations are general guidelines only. It is important that athletes experiment with a variety of strategies and approaches to identify the recovery options that work best for each individual. However, it is known that optimal recovery from training and competition may provide numerous benefits for athlete performance. Recovery strategies such as hydrotherapy, low intensity active recovery, massage, compression garments, stretching or various combinations of these methods may have merit as recovery-enhancing strategies. Importance should also be placed on optimal post-exercise nutrition and adequate sleep to maximise recovery and reduce fatigue from exercise.

REFERENCES

- Ali, A., M.P. Caine, and B.G. Snow (2007). Graduated compression stockings: physiological and perceptual responses during and after exercise. *J. Sports Sci.* 25: 413-419.
- Barnett, A. (2006). Using recovery modalities between training sessions in elite athletes: does it help? *Sports Med.* 36: 781-796.
- Bochmann, R.P., W. Seibel, E. Haase, V. Hietschold, H. Rodel, and A. Deussen (2005). External compression increases forearm perfusion. *J. Appl. Physiol.* 99: 2337-2344.
- Bond, V., R.G. Adams, R.J. Tearney, K. Gresham, and W. Ruff (1991). Effects of active and passive recovery on lactate removal and subsequent isokinetic muscle function. *J. Sports Med. Phys. Fit.* 31: 357-361.
- Carter, R., 3rd, T.E. Wilson, D.E. Watenpugh, M.L. Smith, and C. G. Crandall (2002). Effects of mode of exercise recovery on thermoregulatory and cardiovascular responses. *J. Appl. Physiol.* 93: 1918-1924.
- Coffey, V., M. Leveritt, and N. Gill (2004). Effect of recovery modality on 4-hour repeated treadmill running performance and changes in physiological variables. *J. Sci. Med. Sport* 7: 1-10.
- Dawson, B., S. Cow, S. Modra, D. Bishop, and G. Stewart (2005). Effects of immediate post-game recovery procedures on muscle soreness, power and flexibility levels over the next 48 hours. *J. Sci. Med. Sport* 8: 210-221.
- Duffield, R., J. Cannon, and M. King (2010). The effects of compression garments on recovery of muscle performance following high-intensity sprint and plyometric exercise. *J. Sci. Med. Sport* 13: 136-140.
- Halson, S.L. (2011). Does the time frame between exercise influence the effectiveness of hydrotherapy for recovery? *Int. J. Sports Physiol. Perform.* 6: 147-59.
- Hamlin, M.J. (2007). The effect of contrast temperature water therapy on repeated sprint performance. *J. Sci. Med. Sport* 10: 398-402.
- Hill, J., G. Howatson, K. van Someren, J. Leeder, and C. Pedlar (2013). Compression garments and recovery from exercise-induced muscle damage: a meta-analysis. *Br. J. Sports Med.* Epub ahead of print. PMID: 23757486.
- Ingram, J., B. Dawson, C. Goodman, K. Wallman, and J. Beilby (2009). Effect of water immersion methods on post-exercise recovery from simulated team sport exercise. *J. Sci. Med. Sport* 12: 417-421.
- King, M., and R. Duffield (2009). The effects of recovery interventions on consecutive days of intermittent sprint exercise. *J. Strength Cond. Res.* 23: 1795-1802.
- Kinugasa, T., and A. E. Kilding (2009). A comparison of post-match recovery strategies in youth soccer players. *J. Strength Cond. Res.* 23: 1402-1407.
- Kokkinidis, E., A. Tsamourtas, P. Buckenmeyer, and M. Machairidou (1998). The effect of static stretching and cryotherapy on the recovery of delayed muscle soreness. *Exerc. Soc. J. Sport Sci.* 19: 45-53.
- Kraemer, W.J., J.A. Bush, R.B. Wickham, C.R. Denegar, A.L. Gomez, A.L. Gotshalk, N.D. Duncan, J.S. Volek, R.U. Newton, M. Putukian, and W.J. Sebastianelli (2001). Continuous compression as an effective therapeutic intervention in treating eccentric-exercise-induced muscle soreness. *J. Sport Rehab.* 10: 11-23.
- Lane, K.N., and H.A. Wenger (2004). Effect of selected recovery conditions on performance of repeated bouts of intermittent cycling separated by 24 hours. *J. Strength Cond. Res.* 18: 855-860.
- Leeder, J., C. Gissane, K. van Someren, W. Gregson, and G. Howatson (2012). Cold water immersion
- Lum, D., G. Landers, and P. Peeling (2010). Effects of a recovery swim on subsequent running performance. *Int. J. Sports Med.* 31: 26-30.
- Menzies, P., C. Menzies, L. McIntyre, P. Paterson, J. Wilson, and O. J. Kemi (2010). Blood lactate clearance during active recovery after an intense running bout depends on the intensity of the active recovery. *J. Sports Sci.* 28: 975-82.
- Miladi, I., A. Temfemo, S.H. Mandengua, and S. Ahmaidi (2011). Effect of recovery mode on exercise time to exhaustion, cardiorespiratory responses, and blood lactate after prior, intermittent supramaximal exercise. *J. Strength Cond. Res.* 25: 205-210.
- Monedero, J., and B. Donne (2000). Effect of recovery interventions on lactate removal and subsequent performance. *Int. J. Sports Med.* 21: 593-597.
- Montgomery, P.G., D.B. Pyne, W.G. Hopkins, J.C. Dorman, K. Cook, and C.L. Minahan (2008). The effect of recovery strategies on physical performance and cumulative fatigue in competitive basketball. *J. Sports Sci.* 26: 1135-1145.
- Ogai, R., M. Yamane, T. Matsumoto, and M. Kosaka (2008). Effects of petrissage massage on fatigue and exercise performance following intensive cycle pedalling. *Br. J. Sports Med.* 42: 834-838.
- Rowell, G.J., A.J. Coutts, P. Reaburn, and S. Hill-Haas (2009). Effects of cold-water immersion on physical performance between successive matches in high-performance junior male soccer players. *J. Sports Sci.* 27: 565-573.
- Tiidus, P.M. and J.K. Shoemaker (1995). Effleurage massage, muscle blood flow and long-term post-exercise strength recovery. *Int. J. Sports Med.* 16: 478-483.
- Vaile, J., S. Halson, N. Gill, and B. Dawson (2008a). Effect of cold water immersion on repeat cycling performance and thermoregulation in the heat. *J. Sports Sci.* 26: 431-440.
- Vaile, J., S. Halson, N. Gill, and B. Dawson (2008b). Effect of hydrotherapy on recovery from fatigue. *Int. J. Sports Med.* 29: 539-544.
- Vaile, J., S. Halson, and S. Graham (2010). Recovery Review: Science vs. Practice. *J. Aust. Strength Cond. Suppl.* 2: 5-21.
- Versey, N., S. Halson, and B. Dawson (2011a). Effect of contrast water therapy duration on recovery of cycling performance: a dose-response study. *Eur. J. Appl. Physiol.* 111: 37-46.
- Versey, N. G., S.L. Halson, and B.T. Dawson (2011b). Effect of contrast water therapy duration on recovery of running performance. *Int. J. Sports Physiol. Perform.* 7: 130-140.
- Versey, N.G., S.L. Halson, and B.T. Dawson (2013). Water Immersion Recovery for Athletes: Effect on Exercise Performance and Practical Recommendations. *Sports Med.* Epub ahead of print. PMID: 23743793.
- Weerapong, P., P.A. Hume, and G.S. Kolt (2005). The mechanisms of massage and effects on performance, muscle recovery and injury prevention. *Sports Med.* 35: 235-256.
- Wilcock, I.M., J.B. Cronin, and W.A. Hing (2006). Physiological response to water immersion: a method for sport recovery? *Sports Med.* 36: 747-765.
- Wiltshire, E.V., V. Poitras, M. Pak, T. Hong, J. Rayner, and M.E. Tschakovsky (2010). Massage impairs postexercise muscle blood flow and "lactic acid" removal. *Med. Sci. Sports Exerc.* 42: 1062-1071.