

Recovery and Adaptation

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by William A. Sands

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Introduction

Is systematic recovery necessary for the modern athlete, and are prescribed recovery activities effective? As the developing field of modalities to promote athlete recovery in training moves beyond its first baby-steps, we see there are numerous paradoxes and uncertainties that make this a difficult question to answer. For example, prior to the 2008 Olympic Games, Australian sport scientists concluded that traditional and well-accepted methods such as sufficient nutrition, hydration, and rest appear to be the more effective for optimising recovery in Olympic athletes than newer, more exotic strategies¹. Another study found that athletes using the Recovery Center at the U.S. Olympic Committee's Training Centre showed a negative relationship with medals won, in other words, those who used the available advanced recovery modalities the most fared less well in competition. Interestingly, three decades ago, VERKHOSHANSKY was already thinking along these lines when he identified the potential conflict of using artificial restorative means that may contaminate the natural recovery process².

Paradoxes usually indicate incomplete understanding and it must be said that conceptual and definitional problems continue to plague recovery studies. Most definitions infer a return to a homeostatic state following a training-induced disturbance. KELLMANN defined recovery as the compensation of deficit states of an organism (e.g., failure or decrease in performance) and, according to the homeostatic principle, a reestablishment of the initial state³. However, I for one believe that recovery defined by a return to prior conditions is insufficient for use in training for high-performance sport. A unity of recovery and adaptation (RA), like that described by STONE et al.^{4,5}, is more relevant.

The aim of this article is to help advance the work of scientists and practitioners by providing an overview of the field, including the latest thinking on various RA strategies, as the basis for further discussion and study.

Fatigue-Recovery-Adaptation

Establishing a unity of training and recovery and adaptation as expressed by HARRE is essential for the effectiveness of athletic training. Training causes fatigue and temporarily lowers performance but also sets off two processes that may temporarily run along parallel lines:

- the recovery process leading to the re-establishment of the full ability to function,
- the adjustment or adaptation processes leading to the functional improvement of performance and the morphological reorganisation of the functional systems under stress⁶.

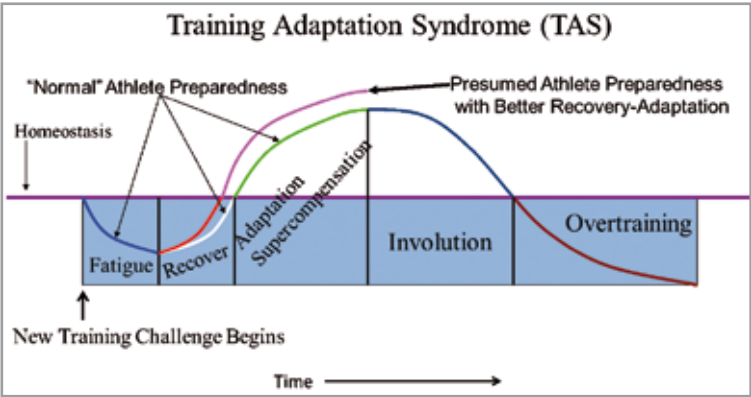


Figure 1: General schematic of the stages of training with and without enhanced recovery and adaptation

Figure 1 shows a schematic of the progress of a training stimulus and response resulting in early fatigue followed by RA.

Fatigue results in a reversible decline in biological systems. Importantly, it may be present *before* a marker of physiological or psychological task failure is observed⁷. Fatigue and

RA appear to share feedforward and feedback pathways both sequentially and simultaneously⁷⁻⁹. There are also aspects of force production and regulation, important keys to athletic performance, that share these pathways. Fatigue expression may involve a threshold: below it, fatigue may be present but not influencing performance, above it, performance declines.

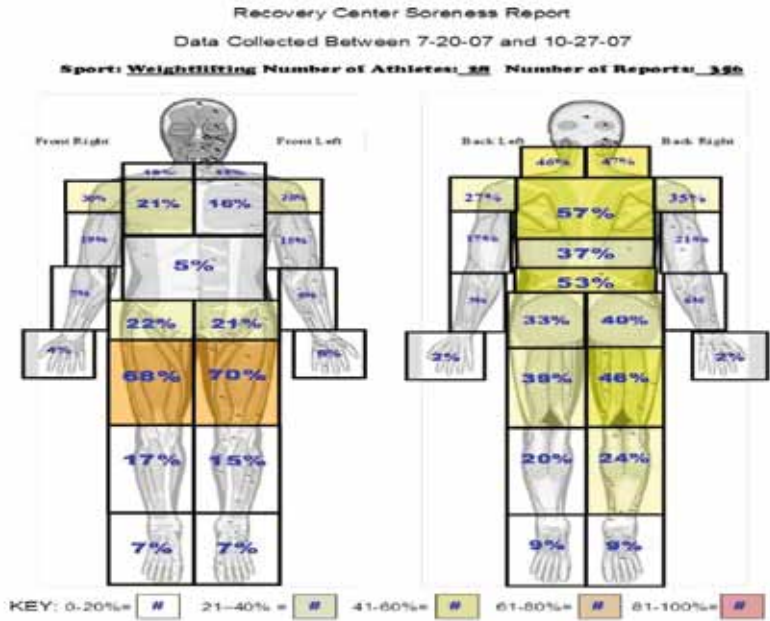


Figure 2: Example of body area fatigue, pain, and soreness of weightlifters from the U.S. Olympic Training Center (Note the differences in percentages of reports for various body areas.)

If fatigue is present with no impaired performance, available methods of detection are lacking. However, if fatigue is cumulative, the background and undetectable aspects merit research.

Sources and regulation of fatigue may be central, peripheral, or both. Muscle performance studies regularly distinguish between peripheral (i.e. from the neuromuscular junction to the protein filaments) and central (i.e. proximal to the neuromuscular junction to the cerebrum). Peripheral fatigue is defined by two characteristics: 1) an exercise-induced force or power reduction, regardless of task completion⁹, and 2) inability to maintain a maximal or expected force or power level¹⁰. Central fatigue is a progressive, exercise-induced reduction in voluntary activation of a muscle¹¹.

In spite of previous work demonstrating different types, locations and sources of fatigue, most work on recovery does not address the

possibility of different types of RA targeting different locations or sources of the fatigue and its regulation. Figure 2 shows the body areas in most need of recovery based on fatigue, pain and soreness reported by Olympic-level weightlifters.

It is important to note that RA strategies and techniques are not sufficiently powerful to overcome stupid coaching, bad planning or lack of talent. Moreover, it is essential for athletes to inform the coach of their fatigue status. With that said, modern training theory and psychophysiology present three broad categories of concepts for RA:

- Training planning,
- Physical RA,
- Psychological RA.

Training Planning

There are at least a dozen training planning models, most with subtypes, and a number of training and recovery guidelines are discussed

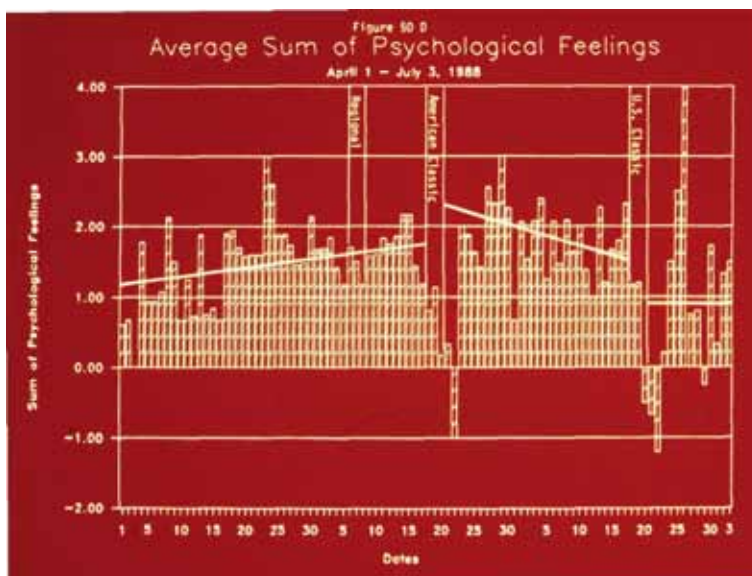


Figure 3: Data showing the psychological mood state results of national team gymnasts leading to Olympic Trials¹⁸ with the sum of positive and negative values shown (Note the dramatic decline in mood states following the American Classic and U.S. Classic competitions. Qualification to the Olympic Trials was achieved by high rankings at these two competitions. None of these athletes attended the regional competition. The psychological decline following these competitions was exacerbated by a general decline in mood states, related to accumulated fatigue, in these athletes¹⁸.)

in the extant literature. A common theme among these is that RA activities should be systematically planned^{4, 12, 13} with the following principles and considerations identified:

- RA activities can be withheld when appropriate in order to enhance the body's ability to heal itself. It is necessary to consider that immediate use of artificial means that help restoration weaken the natural ability of the body to restore itself¹⁴.
- Variation of RA activities is important because athletes become adapted to a particular form with reduced efficacy from continued treatments. Therefore, long-term use of any given means of restoration has a decreasing recuperative effect, as the body adapts more rapidly to local-effect means than to general means¹⁴.
- RA effects tend to be short-lived, especially following high-intensity training, lasting from hours to the next day¹⁵.
- Rest does not mean bed rest, it simply means **active rest** for those fatigued from short-duration, high-intensity training. Athletes fatigued by long-duration, low-intensity training require **calm rest**¹⁶.
- Athletes incorporate RA strategies and modalities on their own.
- Relaxation may be a foreign idea to some athletes, and systematic instruction may be needed to help the athlete learn to relax¹⁷.
- Both sleep duration and quality are important for RA, provisions for adequate sleep should be included in training plans¹⁶.
- Local and systemic recovery strategies should be planned and implemented. Local RA occurs more quickly and easily than systemic RA¹⁴.
- A day or two of active rest following a competition is recommended (Figure 4)^{5, 18, 19}.
- Every training programme should be combined with a monitoring programme of training dose-response relationships^{5, 20}.

The goal of training planning is an optimal training load for each athlete, implying that training activities are sufficiently stressful to challenge and fatigue the athlete, and that these are punctuated by rest. Figure 4 is a schematic of the concept of optimisation with training loads that are too little, too much, and just right^{2, 21}.

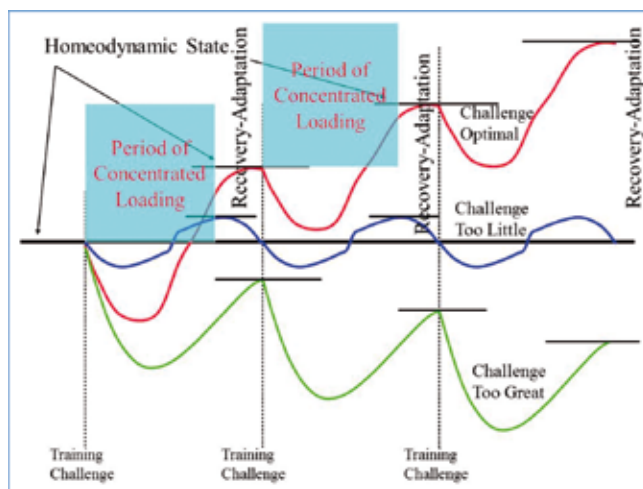


Figure 4: A theorised optimal path of adaptation and recovery adaptation contrasted to two other paths exhibiting non-optimal adaptation (Note periods of hard training followed by periods of rest (recovery-adaptation).)

Training plans may be developed in many ways. A common planning method uses an annual plan form²². However, specific RA activities in such plans are rare. An example of an annual plan *with* RA activities is shown in Figure 5.

Rest and Sleep

Modern life tends to intrude frequently on an athlete's time for rest and measuring rest is difficult. In fact, rather than measure rest, we measure a pertinent negative - the **absence** of known responses to stress. For example, the Rusko Test exploits the known response to orthostatic changes by comparing morning heart rates in a lying position with those observed after standing (i.e. orthostatic intolerance)^{23, 24}.

When heart rate variability is relatively low, we assume that the athlete is stressed. Figure 6 shows an example of Rusko Test results from a synchronised swimming national team athlete showing that the standing heart rate was too high, indicating that RA was incomplete.

In the RA paradigm, the detection of the presence of RA is based on the absence of fatigue markers. Demonstrating an absence of fatigue markers is, in turn, based on the presence of adaptation (i.e. recovered) performance.

Sleep

Sleep studies involving elite athletes are rare²⁵. Sleep loss is known to reduce cognitive effectiveness²⁵. However, the complex nature of sleep betrays the fact that many people, especially those in high-stress situations, cannot obtain the sleep that is refreshing and regenerating²⁶. Shortening the sleep period to 4-6 hours per night for four or more nights in a row resulted in disturbed mood states and reduced cognitive abilities²⁷. One of the simplest recommendations for sleep is that people should obtain at least eight hours of sleep per night²⁸. However, there appear to be wide variations in individual sleep duration needs.

Napping may hold benefits for those who must live and perform with less than optimal sleep²⁵. A 30-minute lunchtime nap was shown to decrease sprint times and increase alertness when compared to a no-nap control group²⁹. Naps can also enhance learning and other cognitive abilities³⁰.

A common complaint arising from naps is the phenomenon of sleep inertia, the feeling of drowsiness or sluggishness that may follow a nap³¹. A study of 20-minute naps to simulate jetlag showed no benefits to performance³². The regulation of sleep and sleep inertia may rely on limb temperature during sleep, particularly of the hands and feet. Increased distal skin temperatures are related to short sleep onset while sleep inertia may represent a thermal reversal of sleep-onset (i.e. warmer hands and feet)³³.

Extending the idea of adequate sleep, MAH et al. showed that increased sleep duration resulted in better performance in basketball³⁴. The subjects in this study underwent a five- to seven-week period of extended sleep. Their minimum goal was to achieve 10-hours of sleep per day. Basketball skills and several laboratory measures showed improvement³⁴. When early morning practices and training are imposed, there is an increased perception of fatigue and a decrease in normal sleep duration³⁵.

Blood and Lymphatic Flow

The majority of RA approaches involve increasing blood and lymphatic flow. Fluid flow is encouraged by light exercise, thermal therapies (hot and cold), mechanical devices (compression), nutrition (protein and carbohydrate timed feedings), touching (massage), and increased comfort. Exercise-induced oedema is an important aspect of all exercise³⁶. The inflammatory cascade regulates and assists healing in muscle and other tissues during and following training³⁷. Pain is a common complaint following hard training. Thus, control of the magnitude of oedema and the body's ability to reduce pain is a fruitful area for study and RA strategies.

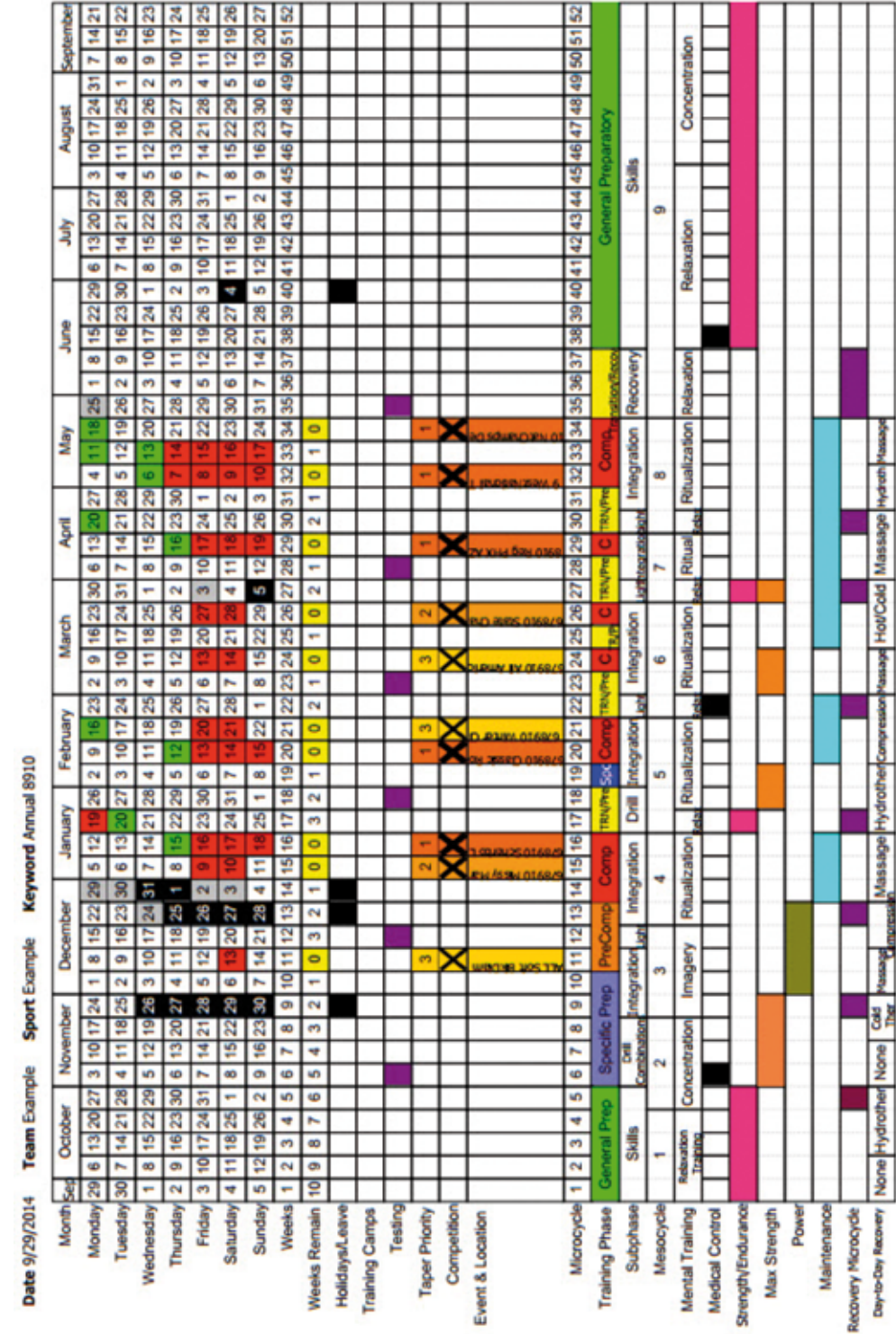


Figure 5: Example annual plan including recovery-adaptation scheduling

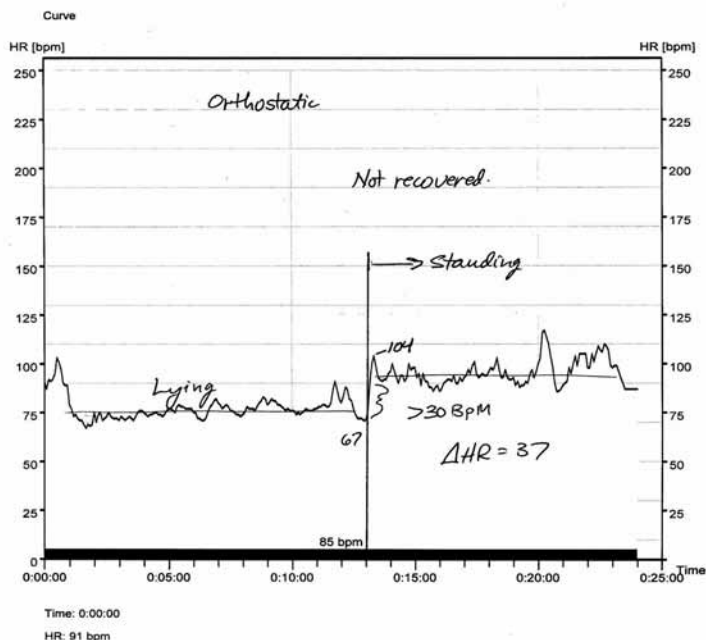


Figure 6: An example of the application of the Rusko Test of orthostatic tolerance (The athlete applies a heart rate monitor with storage capabilities upon awakening but before rising from bed. After a few minutes of lying heart rate measurements, the athlete suddenly stands up and the heart rate is recorded continuously. Large differences between lying and standing heart rates may indicate a lack of recovery and adaptation from the previous day's training. The handwritten annotations demonstrate how rapidly this information can be returned to coaches.)

Light Exercise and Active Rest

One of the simplest means of increasing blood flow is light exercise. Lowering of lactate, heart rate, and better Profile of Mood States results were obtained by low-intensity cycling in trained cyclists³⁸. Increased blood flow is more likely to be encouraged by active rather than passive rest. Lactate elimination and better subsequent performance following judo combat exercise were promoted more by active rest³⁹. Perhaps the best fate of post-exercise lactate is consumption by active muscle, but the muscle activity for RA should not be great enough to produce new lactate. Cycling at 40% of VO_2 max was better at eliminating post-exercise (15-20 min) lactate than massage or passive recovery⁴⁰. GILL et al. showed an increased effectiveness of RA in rugby players following a match by using active recovery (light exercise), hydrotherapy, and a compression garment⁴¹. Massage and passive recovery

were ineffective in lactate removal when compared to active recovery⁴². A recovery swim with runners led to enhanced next day running performance, possibly due to the hydrostatic properties of water⁴³.

Thermal Therapies

Heat packs and heating pads have been a mainstay of sport therapy and self-administered treatments for decades⁴⁴. Moist heat packs were shown to be effective in hamstring muscle range of motion when compared to stretching alone⁴⁵. Hot baths, steam baths, and saunas are also common RA practices. SOBOLEVSKY describes the methods for sound sauna use along with precautions for young athletes⁴⁶. SANDS (In Press) studied hydration in Olympic level athletes using a sauna and steam bath, insisting on fluid ingestion during use. Urine specific gravity values did not show dehydration, and body weight

increased following sauna and steam bath use. Anecdotal support for sauna use among Finnish athletes was provided by REHUNEN⁴⁷. A study of delayed onset muscle soreness (DOMS) showed that only superficial heat was effective in reducing DOMS as compared to cold and control⁴⁸.

Applications of Cold

Cryotherapy (i.e. application of cold) has been a method of choice for injury rehabilitation, reduction of oedema, and blood circulation enhancement for centuries. Cryotherapy has been applied for immediate wound care, sprains and strains, chronic injuries, before and after surgery, and as a modality for RA⁴⁹. Inter-set weight pulling performance has been enhanced by the application of cold⁵⁰. Cold-water immersion has been found to aid recovery in cyclists⁵¹. Whole-body cryotherapy using a chamber cooled by liquid nitrogen to minus 135°C for several minutes is being used for RA. Reports on this type of therapy have included RA and other types of rehabilitation and have been largely Favorable⁵²⁻⁵⁴. Figure 5 shows the author and colleagues about to enter a Cryotherapy chamber. Recovery centre surveys of athletes' preferences for various therapies indicate that cold-water immersion ranks second only to massage (SANDS, in press).

Cryotherapy has recently been questioned based on investigations of the use of cold on oedema and the inflammatory cascade following injury⁵⁵. MIRKIN, who coined the acronym RICE – Rest, Ice, Compression, and Elevation – in 1978⁵⁶ now finds that complete rest and ice prolong the disability and delay healing. Inflammation is necessary for healing, and the role of inflammation appears to have been misjudged⁵⁵. Ice therapy has also been shown to delay healing after intense eccentric exercise⁵⁷.

Moreover, the inflammatory process and immune response to injury, whether exercise-induced or from trauma, requires complex interactions of many physiological pathways and specialised cells of the immune system⁵⁸. Whole-body cold immersion resulted in de-

creased strength values, although the declines were small⁵⁹. A DOMS experiment using cold-water showed a minimal effect⁶⁰. The most current information indicates that anything that interrupts or delays circulation, or alters the inflammatory cascade is probably not ideal for enhancing RA.

Static Compression

Reduction of exercise-induced oedema is an important aspect of RA and often a key to healing^{37, 61}. Static compression garments in the form of stockings and leggings or tights are available in both graduated- and non-graduated pressure-types. Graduated garments are designed to exert greater pressure in some regions, usually circumferentially, with higher pressures distally. The elastic nature of the garments combined with motion of the limb can be used to assist the sequential nature of compression and fluid flow. Non-graduated stockings enhanced running in moderately trained runners with lower leg problems, however these runners also improved their aerobic capacity during the study making determination of the source of the change difficult⁶².

Eccentric exercise results in limb volume changes indicative of oedema following exercise trials⁶³. KRAEMER et al. conducted two studies involving the use of compression sleeves in untrained females that showed decreased perceived soreness, reduced oedema and enhanced recovery⁶⁴. In a subsequent study of resistance-trained women and men, a whole-body compression garment worn for 24 hours following training resulted in improved recovery⁶⁵. A study of recreationally active men wearing graduated compression stockings during a 10km time trial showed less DOMS than those running without stockings⁶⁶. Upper and lower body compression garments in a resistance training setting showed better recovery in the upper body and improved but delayed recovery in the lower body⁶⁷.

A meta-analysis of compression garments concluded that the garments are effective methods to enhance RA⁶⁸. In contrast,

no physiological benefits were observed in a study of compression garments used by males and females following a marathon but the perceived soreness was lower in the garment group⁶⁹. Questions around the value of compression garment use remain open, but this modality appears promising⁷⁰.

Intermittent Peristaltic Compression (IPC)

IPC involves *dynamic compression* via a computer-controlled air pressure pump connected to a legging or sleeve. The basic premise is that pressures in a sequential, peristaltic fashion more closely mimics natural fluid flow and is thereby more effective. IPC requires a device that provides circumferential pressures to a limb, moving from distal to proximal (Figure 7).

The use of IPC has been shown to be effective for prevention of oedema formation, increasing blood flow, and stimulation of tissue healing. Although static compression is an effective therapy for oedema reduction, the intermittent compression optimises lymphatic drainage. IPC can accelerate recovery from either intense exertion or injury, especially when the athlete is incapable of generating rhythmic muscle contractions. Improved lymphatic

function accelerates healing through the removal of oedema from injured soft tissues⁷¹. An advantage of IPC is the intermittent nature of the applied pressure allowing the pressure to be greater than that achieved using static pressure or applied manually by a therapist.

The primary RA mechanism of IPC is enhanced lymphatic drainage and fluid return that accelerates circulatory responses and the removal of edema-containing waste products and damaged tissues⁷². Dynamic compression can improve healing through oedema reduction, stimulation of platelet aggregation, and neutrophil adherence⁷¹. Dynamic compression has been shown to enhance both fractures and soft-tissue healing⁷³, and pressure to pain threshold among Olympic level athletes^{74, 75}.

IPC may also be better than static compression based on the fragility of lymphatic vessels and valves⁷⁶. The intermittent nature of IPC may allow the fragile valves of lymphatic and capillary vessels to open. MARTIN et al. found that IPC did not reduce lactate values immediately but did so later. These investigators postulate that IPC could be useful for those athletes needing a form of inactive recovery⁷⁷.



Figure 7: About to enter the Kriotherapy Chamber at -135° in London, UK (The masks are needed to prevent sudden freezing of water in the mouth, nose, and on the lips.)

In contrast with many RA modalities, there appears to be less contradictory evidence regarding the effects of IPC on RA. However, the individual device pressures and the durations and sequences of the pressures remain to be investigated.

Compassionate Touch Therapy-Massage

Studying massage is difficult both because of the myriad techniques and because the rapport factor that appears to dictate the efficacy of much of the massage process^{78, 79}. Massage appears to be a promising method for RA, but nearly all reviews and studies indicate that more high-quality research is needed, and that the mechanisms are poorly understood⁸⁰.

Massage therapy elicits a great deal of faith in its effectiveness from practitioners and recipients but most studies of DOMS and massage have shown serious methodological flaws and extant studies are equivocal on the effectiveness of massage. For example, an excellent review article on massage and DOMS concluded that massage is promising in reducing soreness but shows limited results in transfer to performance enhancement⁷⁸. In spite of these problems, most investigators suggest that post-exercise massage may alleviate the symptoms of DOMS^{81, 82}.

HEMMINGS et al. raised questions about the efficacy of massage in a study of physiological and psychological recovery stating that massage may be beneficial psychologically but not physiologically⁸³. NELSON⁷⁸ also noted that observations of massage effects were more easily shown in the psychological than the physiological domain.

The physiology of touch has recently received important support from the discovery of *touch neurons*⁸⁴⁻⁸⁶ called C-tactile neurons. These afferent neurons are found in the hairy regions of the body and provide light touch feedback. Results indicate that C-tactile afferents constitute a privileged peripheral pathway for pleasant tactile stimulation that is likely to

signal affiliative social body contact⁸⁵. MC-GLONE et al. described the neurons as, a class of low-threshold mechanosensitive C fibres that innervate the hairy skin represent the neurobiological substrate for the affective and rewarding properties of touch⁸⁶. Thus, the physiological mechanism for the pleasant nature of massage may have been identified.

Nutritional Therapies

Nutritional interventions are perhaps the least controversial of all RA modalities. Those interventions known to enhance performance are creatine, hydration, carbohydrate loading, and supplemental protein. For example, when exercise is followed by carbohydrate feeding subsequent performance is augmented and when carbohydrate feeding is withheld subsequent performance declines⁸⁷. A likely influence on central fatigue and recovery was shown from simply rinsing the mouth with a carbohydrate solution that further resulted in decreased fatigue⁸⁸. However, carbohydrate and caffeine mouth rinsing did not enhance strength or muscular endurance⁸⁹.

Carbohydrate alone and in combination with other nutrients is important in brain tissue recovery⁸ and carbohydrate ingestion may alter neurotransmitter actions. The neurotransmitter serotonin is influenced by its precursor tryptophan. Tryptophan crosses the blood-brain barrier by binding to albumin. Albumin is reduced by carbohydrate interactions with fat metabolism along with tryptophan⁹⁰. Decreasing the precursors of serotonin or the relations of serotonin to dopamine and other neurotransmitters, is potentially important for recovery because of the relationship of serotonin to moods, depression, and sleepiness^{8, 91, 92}.

Nutrient Timing

Although nutrient timing and content has recently been shown to be somewhat less powerful than originally thought, work in this area has been one of the most important additions to modern training science. There appears to be a window of optimal nutrient intake



Figure 8: Lower extremity IPC therapy

from approximately 45 minutes to one hour post-exercise⁹³. The combination of protein and carbohydrate in chocolate milk has been identified as an ideal source of post-exercise nutrition⁹⁴⁻⁹⁹. Other research supports the idea that carbohydrates are the most important macronutrient along with water and protein following exercise^{100, 101}. A carbohydrate and protein supplement, while not improving performance, appeared to reduce muscle damage based on assessments of myoglobin and creatine kinase¹⁰².

The International Society of Sports Nutrition developed a consensus position statement, which indicates that specific amino acid supplements, particularly branched chain amino acids, improve RA¹⁰³. However, there are still some enigmatic aspects of nutrition in RA. For example, a study of the benefits of fast food versus sports supplements showed no difference in glycogen resynthesis following exercise¹⁰⁴. If fast food can compete with designed sport supplements, then nutrition education may need recalibration.

Psychological Therapies

Application of recovery modalities usually occurs when the athlete is most vulnerable. The athlete is often physically exhausted, in pain, and cognitively deficient. Experience has shown that compassionate discourse, a strong social support network, and athlete confidence are good indicators of the success of RA¹⁰⁵. The human-to-human activities in sports recovery often involve caring conversation (e.g. counseling), compassionate touching (e.g. massage), and other close personal contact^{106, 107}. SIFF wrote about athlete recovery, suggesting that often one cannot separate the therapy from the therapist, since the therapy works because of the rapport between therapist and client⁷⁹.

Mental Fatigue

The concept of mental fatigue is certainly not new and occupies a common sense position in everyday discourse. Mental fatigue is a psychophysiological state that is the result of prolonged cognitive activity and can impair physical performance¹⁰⁸. Here, again, is an example of the potential role of central fatigue in athletic performance and emphasises a need for further investigations of methods designed

to understand central fatigue and enhance central recovery.

Mental fatigue tends to be cumulative and gradually acquired when compared to physical fatigue. In the ergonomics world, mental fatigue and recovery have been described with the following:

A distinction is made between 'physical fatigue' and 'mental fatigue' and its consequences for recovery. The discrepancy between 'actual state' and 'required state' has been suggested as the basis for 'recovery'. This emphasis, that recovery is a dynamic and ongoing process, which also included motivational aspects, in particular as far as mental work is concerned. The capacity to maintain self-regulation of one's psychophysiological state is important in this respect. Thus, we propose that 'recovery' is the continuous process of harmonising the 'actual state' with the state that is 'required' at that moment¹⁰⁹.

Mental fatigue has been shown to reduce time to exhaustion in high-intensity cycling¹¹⁰. Mental fatigue resulted in worse intermittent sprint performance variables such as lower oxygen consumption and greater ratings of perceived exertion¹¹¹. The preceding authors and others have subsequently found that mental fatigue does not have deleterious effects on whole body endurance exercise, sustained isometric tension, peak sprint velocities, and some mood variables¹¹¹⁻¹¹³. The paradox described by these authors has been postulated to result from the activity of higher brain centers in self-regulation of effort¹¹³.

In spite of some paradoxical issues regarding the role of psychophysiological states on fatigue, and RA, and that of psychological investigations in general^{114, 115}, there is little doubt that psychological factors play an important role in RA¹¹⁶⁻¹¹⁸. Athlete attitudes and volition may increase the variability of performance and psychological responses, and thus the experimental difficulties of cause and effect. Mental toughness and the ability to relax are considered essential RA characteristics^{119, 120}.

Mental Resilience

Mental resilience is one of the newer concepts involved in one's ability to handle stress and "bounce back" from stress and fatigue¹²¹⁻¹²³. However, hardiness and optimism failed to predict past staleness in high school age male and female endurance athletes¹²⁴. Again, SIFF embraced the paradoxes, contradictions, and difficulties in RA research, particularly psychological factors suggesting that certainly many of these techniques work because they are placebos, because the user believes in them. Yet, this is a very good reason not to dismiss them. If the mind can be focused by an apparently illogical or foolish concept to perform unusual feats of performance or healing, then it is vital that we uncover the underlying physiological principles that make the placebo effect (or 'faith factor') so powerful. Placebos can produce positive and negative effects; it is up to science to sift the useful from the harmful¹²⁵. Like massage, we tend to have faith that psychological factors are involved in RA, in spite of limited and contradictory evidence.

Conclusion

Recovery-adaptation is both new and old, with modern approaches facing new scrutiny. Research in RA is very young and full of uncertainty. There are many obstacles to the study of RA. One of the most serious obstacles is the lack of a theoretical or mechanistic framework from which to design studies and guide RA modality implementation. Perhaps, with apologies to Tolstoy, we can say that all recovered athletes are the same, but each unrecovered athlete is unrecovered in his or her own way.

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REFERENCES

1. ROBSON-ANSLEY, P.J.; GLEESON, M. & ANSLEY, L. (2009) Fatigue management in the preparation of Olympic athletes. *Journal of Sports Science*, 27: 1409-1420.
2. VERKHOSHANSKY, Y.V. (1985). Programming and organization of training. Moscow, U.S.S.R.: Fizkultura i Sport.
3. KELLMANN, M. (2002). Underrecovery and overtraining: different concepts - similar impact? In: Kellmann M, ed. *Enhancing recovery*. Champaign, IL: Human Kinetics, p 3-24.
4. STONE, M.H. & STONE, M.E. (2003). Recovery-adaptation: strength and power sports. *Olympic Coach*, 15(3): 12-15.
5. STONE, M.H.; STONE, M.E. & SANDS, W.A. (2007). Principles and Practice of Resistance Training. Champaign, IL: Human Kinetics.
6. HARRE D. (1982). Principles of Sports Training. Berlin, German Democratic Republic: Sportverlag.
7. WILLIAMS, C.A. & RATEL, S. (2009). Definitions of muscle fatigue. In: Williams CA, Ratel S, eds. *Human Muscle Fatigue*. London, UK: Routledge, p 3-16.
8. RATTRAY, B.; ARGUS, C.; MARTIN, K.; NORTHEY, J. & DRILLER, M. (2015). Is it time to turn our attention toward central mechanisms for post-exertional recovery strategies and performance? *Front Physiol*, 6: 79.
9. BIGLAND-RITCHIE, B. & WOODS, J.J. (1984). Changes in muscle contractile properties and neural control during human muscular fatigue. *Muscle & Nerve*, 7(9): 691-699.
10. EDWARDS, R.H. (1981). Human muscle function and fatigue. *Ciba Found Symp.*, 82: 1-18.
11. GANDEVIA, S.C.; ALLEN, G.M. & MACKENZIE, D.K. (1995). Central fatigue. In: Gandevia SC, Enoka RM, McComas AJ, Stuart DG, Thomas CK, eds. *Fatigue*. Vol 384. New York, NY: Plenum Press, p 281-294.
12. BRUNNER, R. & TABACHNIK, B. (1990). Soviet training and recovery methods. Pleasant Hill, CA: Sport Focus Publishing.
13. HAUSSWIRTH, C. & MUJIK, I. (2013). Introduction. In: Hausswirth C, Mujika I, eds. *Recovery for Performance in Sport*. Champaign, IL: Human Kinetics, p. xi-xiii.
14. KHOMENKOV, L. (1992). Restoration. In: Siff MC, Yessis M, eds. *Sports Restoration and Massage*. Escondido, CA: Sports Training, Inc. p. 15-18.
15. TALYSHEV, F. (1992). Recovery. In: Siff MC, Yessis M, eds. *Sports Restoration and Massage*. Escondido, CA: Sports Training, Inc., p. 34-35.
16. YAKOVLEV, N. (1992). Fatigue in sports: Its basis and significance. In: Siff MC, Yessis M, eds. *Sports Restoration and Massage*. Escondido, CA: Sports Training, Inc., p. 57-59.
17. MCCLOUGHAN, L.; HANRAHAN, S.; ANDERSON, R. & HALSON, S. (2014). Progressive muscle relaxation (PMR), sleep, and recovery in elite performers. *Journal of Science and Medicine in Sport*, 18: e113.
18. SANDS, W.A. (1990). National women's tracking program pt. 2 - response. *Technique*, 10(1): 23-27.
19. SANDS, W.A. & STONE, M.H. (2006). Are you progressing and how would you know? *Olympic Coach*, 17(4): 4-10.
20. SANDS, W.A. & STONE, M.H. (2006). Monitoring the elite athlete. *Olympic Coach*, 17(3): 4-12.
21. VERKHOSHANSKY, Y. (1998). Organization of the training process. *New Studies in Athletics*, 13(3): 21-31.
22. BOMPA, T.O. & HAFF, G.G. (2009). *Periodization*. Champaign, IL: Human Kinetics.
23. RUSKO, H.K.; RAHKILA, P.; VIHKO, V. & HOLAPPA, H. (1989). Longitudinal changes in heart rate and blood pressure during overtraining period. *Proceedings 1st IOC World Congress on Sport Sciences*, Oct. 28 - Nov. 3. 1:45-46.
24. NORRIS, S.R. & SMITH, D.J. (2002). Planning, periodization, and sequencing of training and competition: the rationale for a competently planned, optimally executed training and competition program, supported by a multidisciplinary team. In: Kellmann M, ed. *Enhancing recovery: preventing underperformance in athletes*. Champaign, IL: Human Kinetics, p. 121-141.
25. HALSON, S.L. (2014). Sleep in elite athletes and nutritional interventions to enhance sleep. *Sports medicine*, 44 Suppl 1: S13-23.
26. VAILE, J. & HALSON, S. (2013). Physiological recovery. In: Tanner RK, Gore CJ, eds. *Physiological Tests for Elite Athletes*. Champaign, IL: Human Kinetics, p. 149-163.
27. BELENKY, G.; WESENSTEN, N.J.; THORNE, D.R. & ET AL. (2003). Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. *Journal of sleep research*, 12(1): 1-12.
28. VAN DONGEN, H.P.; MAISLIN, G.; MULLINGTON, J.M. & DINGES, D.F. (2003). The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*, 26(2): 117-126.
29. WATERHOUSE, J.; ATKINSON, G.; EDWARDS, B. & REILLY, T. (2007). The role of a short post-lunch nap in improving cognitive, motor, and sprint performance in participants with partial sleep deprivation. *Journal of sports sciences*, 25(14): 1557-1566.
30. POSTOLACHE, T.T. & OREN, D.A. (2005). Circadian phase shifting, alerting, and antidepressant effects of bright light treatment. *Clinics in sports medicine*, 24(2): 381-413, xii.
31. ASAOKA, S.; MASAKI, H.; OGAWA, K.; MURPHY, T.I.; FUKUDA, K. & YAMAZAKI, K. (2010). Performance monitoring during sleep inertia after a 1-h daytime nap. *Journal of sleep research*. 19(3): 436-443.
32. PETIT, E.; MOUGIN, F.; BOURDIN, H.; TIO, G. & HAFFEN, E. (2014). A 20-min nap in athletes changes subsequent sleep architecture but does not alter physical performances after normal sleep or 5-h phase-advance conditions. *European journal of applied physiology*, 114(2): 305-315.

33. KRAUCHI, K.; CAJOCHEN, C. & WIRZ-JUSTICE, A. (2005). Thermophysiologic aspects of the three-process-model of sleepiness regulation. *Clinics in sports medicine*, 24(2): 287-300.
34. MAH C.D.; MAH, K.E.; KEZIRIAN, E.J. & DEMENT, W.C. (2011). The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep*, 34(7): 943-950.
35. SARGENT, C.; LASTELLA, M.; HALSON, S.L. & ROACH, G.D. (2014). The impact of training schedules on the sleep and fatigue of elite athletes. *Chronobiol Int.*, 31(10): 1160-1168.
36. KHARRAZ, Y.; GUERRA, J.; MANN, C.J.; SERRANO, A.L. & MUNOZ-CANOVES, P. (2013). Macrophage plasticity and the role of inflammation in skeletal muscle repair. *Mediators Inflamm.*, p.491-497.
37. SCHURMAN, D.J.; GOODMAN, S.B. & LANE SMITH, R. (1990). Inflammation and tissue repair. In: Leadbetter WB, Buckwalter JA, Gordon SL, eds. *Sports-Induced Inflammation*. Park Ridge, IL: American Academy of Orthopaedic Surgeons, p. 277-284.
38. FAUDE, O.; MEYER, T.; URHAUSEN, A. & KINDER-MANN, W. (2009). Recovery training in cyclists: ergometric, hormonal and psychometric findings. *Scandinavian journal of medicine & science in sports*, 19(3): 433-452.
39. FRANCHINI, E.; TAKITO, M.Y.; NAKAMURA, F.Y.; MAT-SUSHIGUE, K.A. & PEDUTI DAL'MOLIN KISS, M.A. (2003). Effects of recovery type after a judo combat on blood lactate removal and on performance in an intermittent anaerobic task. *Journal of Sports Medicine & Physical Fitness*, 43: 424-431.
40. LE MEUR, Y.; DUFFIELD, R. & SKEIN, M. (2013). Sleep. In: Hausswirth C, Mujika I, eds. *Recovery for Performance in Sport*. Champaign, IL: Human Kinetics, p.99-110.
41. GILL, N.D.; BEAVEN, C.M. & COOK, C. (2006). Effectiveness of post match recovery strategies in rugby players. *British journal of sports medicine*, 40: 260-263.
42. GUPTA, S.; GOSWAMI, A.; SADHUKHAN, A.K. & MATHUR, D.N. (1996). Comparative study of lactate removal in short term massage of extremities, active recovery and a passive recovery period after supramaximal sessions. *International journal of sports medicine*, 17(2): 106-110.
43. LUM, D.; LANDERS, G. & PEELING, P. (2009). Effects of a recovery swim on subsequent running performance. *International journal of sports medicine*, 11:Epub ahead of print.
44. DOREL, S. (2013). Local thermal applications. In: Hausswirth C, Mujika I, eds. *Recovery for Performance in Sport*. Champaign, IL: Human Kinetics, p.145-166.
45. FUNK, D.; SWANK, A.M.; ADAMS, K.J. & TREOLO, D. (2001). Efficacy of moist heat pack application over static stretching on hamstring flexibility. *Journal of Strength and Conditioning Research*, 15(1): 123-126.
46. SOBOLEVSKY, V. (1983). Physiological effects of the sauna on young athletes. *Teoriya i Praktika Fizicheskoi Kultury*, 4: 30-32.
47. REHUNEN, S. (1988). The sauna and sports. *Annals of Clinical Research*, 20(4):292-294.
48. SUMIDA, K.D.; GREENBERG, M.B. & HILL, J.M. (2003). Hot gel packs and reduction of delayed-onset muscle soreness 30 minutes after treatment. *Journal of sport rehabilitation*, 12: 221-228.
49. KNIGHT, K.L. (1990). Cold as a modifier of sports-induced inflammation. In: Leadbetter WB, Buckwalter JA, Gordon SL, eds. *Sports-induced Inflammation*. Park Ridge, IL: American Academy of Orthopaedic Surgeons, p. 463-477.
50. VERDUCCI, F.M. (2000). Interval cryotherapy decreases fatigue during repeated weight lifting. *Journal of Athletic Training*, 35(4): 422-426.
51. HALSON, S.L.; BARTRAM, J.; WEST, N. & ET AL. (2014). Does hydrotherapy help or hinder adaptation to training in competitive cyclists? *Medicine and science in sports and exercise*, 46(8): 1631-1639.
52. SCHAAL, K.; LEM, Y.; LOUIS, J. & ET AL. (2015). Whole-Body Cryostimulation Limits Overreaching in Elite Synchronized Swimmers. *Medicine and science in sports and exercise*, 47(7): 1416-1425.
53. BAUER, J. & SKRZEK, A. (2006). Physiological principles of cryotherapy. *Biomedical Engineering Acta.*, 1(1): 21-26.
54. GREGOROWICZ, H. & ZAGROBELNY, Z. (2006). Systemic cryotherapy. Indications and contraindications, process of treatment and its physiological and clinical results. *Biomedical Engineering Acta.*, 1(1): 9-20.
55. MIRKIN G. (2014). Why ice delays recovery. Ice therapy does not promote healing. Available at: <http://drmirkin.com/fitness/why-ice-delays-recovery.html>.
56. MIRKIN, G. & HOFFMAN, M. (1978). *The Sports Medicine Book*. Boston, MA: Little, Brown and Company.
57. TSENG, C.Y.; LEE, J.P.; TSAI, Y.S. & ET AL. (2013). Topical cooling (icing) delays recovery from eccentric exercise-induced muscle damage. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 27(5): 1354-1361.
58. TIDBALL, J.G. (2005). Inflammatory processes in muscle injury and repair. *Am J Physiol Regul Integr Comp Physiol.*, 288(2): R345-353.
59. FROHLICH, M.; FAUDE, O.; KLEIN, M.; PIETER, A.; EMRICH, E. & MEYER, T. (2014). Strength training adaptations after cold-water immersion. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 28(9): 2628-2633.
60. GLASGOW, P.D.; FERRIS, R. & BLEAKLEY, C.M. (2014). Cold water immersion in the management of delayed-onset muscle soreness: is dose important? A randomised controlled trial. *Phys Ther Sport*, 15(4): 228-233.
61. BUTLER, D.L. & SIEGEL, A. (1990). Alterations in tissue responses: Conditioning effects at different ages. In: Leadbetter WB, Buckwalter JA, Gordon SL, eds. *Sports-induced Inflammation*. Park Ridge, IL: American Academy of Orthopaedic Surgeons, p. 713-730.

62. KEMMLER, W.; VON STENGEL, S.; KOCKRITZ, C.; MAYHEW, J.; WASSERMANN, A. & ZAPF, J. (2009). Effect of compression stockings on running performance in men runners. *Journal of Strength and Conditioning Research*, 23(1): 101-105.
63. BOBBERT, M.F.; HOLLANDER, A.P. & HUIJING, P.A. (1986). Factors in delayed onset muscular soreness of man. *Medicine & Science in Sports & Exercise*, 18(1): 75-81.
64. KRAEMER, W.J.; BUSH, J.A.; WICKHAM, R.B. & ET AL. (2001). Influence of compression therapy on symptoms following soft tissue injury from maximal eccentric exercise. *Journal of Orthopaedic & Sports Physical Therapy*, 31(6): 282-290.
65. KRAEMER, W.J.; FLANAGAN, S.D.; COMSTOCK, B.A. & ET AL. (2010). Effects of a whole body compression garment on markers of recovery after a heavy resistance workout in men and women. *Journal of Strength and Conditioning Research*, 24(3): 804-814.
66. ALI, A.; CAINE, M.P. & SNOW, B.G. (2007). Graduated compression stockings: Physiological and perceptual responses during and after exercise. *Journal of sports sciences*, 25(4): 413-419.
67. GOTO, K. & MORISHIMA, T. (2014). Compression garment promotes muscular strength recovery after resistance exercise. *Medicine and science in sports and exercise*, 46(12): 2265-2270.
68. HILL, J.; HOWATSON, G.; VAN SOMEREN, K.; LEEDER, J. & PEDLAR, C. (2014). Compression garments and recovery from exercise-induced muscle damage: a meta-analysis. *British journal of sports medicine*, 48(18): 1340-1346.
69. HILL, J.A.; HOWATSON, G.; VAN SOMEREN, K.A.; WALSH, I. & PEDLAR, C.R. (2014). Influence of compression garments on recovery after marathon running. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 28(8): 2228-2235.
70. BELIARD, S.; CHAUVEAU, M.; MOSCATIELLO, T.; CROS, F.; ECARNOT, F. & BECKER, F. (2015). Compression garments and exercise: no influence of pressure applied. *Journal of sports science & medicine*, 14(1): 75-83.
71. CAPPS, S.G. (2009). Cryotherapy and intermittent pneumatic compression for soft tissue trauma. *Athletic Therapy Today*, 14 (1): 204.
72. HAVAS, E.; PARVIANEN, T.; VUORELA, J.; TOIVANEN, J.; NIKULA, T. & VIHKO, V. (1997). Lymph flow dynamics in exercising human skeletal muscle as detected by scintigraphy. *Journal of Physiology*, 504(Pt 1): 233-239.
73. KHANNA, A.; GOUGOULIAS, N. & MAFFULI, N. (2008). Intermittent pneumatic compression in fracture and soft-tissue injuries healing. *British medical bulletin*, 88: 147-156.
74. SANDS, WA (2014). Dynamic compression for recovery in athletes. [Web page] <http://lernmagazine.com/article/dynamic-compression-for-recovery-in-athletes>: Peristaltic pulse compression in recovery. Available at. Accessed 30 August 2014.
75. SANDS, W.A.; MCNEAL, J.R.; MURRAY, S.R. & STONE, M.H. (2015). Dynamic Compression Enhances Pressure-to-Pain Threshold in Elite Athlete Recovery: Exploratory Study. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 29(5): 1263-1272.
76. LYNCH, P.M.; DELANO, F.A. & SCHMID-SCHONBEIN, G.W. (2007). The primary valves in the initial lymphatics during inflammation. *Lymphatic research and biology*, 5(1): 3-10.
77. MARTIN, J.S.; FRIEDENREICH, Z.D.; BORGES, A.R. & ROBERTS, M.D. (2015). Acute Effects of Peristaltic Pneumatic Compression on Repeated Anaerobic Exercise Performance and Blood Lactate Clearance. *Journal of strength and conditioning research / National Strength & Conditioning Association*. 28(8): 2071-2373.
78. NELSON, N. (2013). Delayed onset muscle soreness: is massage effective? *Journal of bodywork and movement therapies*, 17(4): 475-482.
79. SIFF, M.C. (1992). Stress management and restoration. In: Siff MC, Yessis M, eds. *Sports restoration and massage*. School of Mechanical Engineering, University of Witwatersrand, South Africa: School of Mechanical Engineering, University of Witwatersrand, p.1-12.
80. MORASAKA, A. (2005). Sports massage. A comprehensive review. *Journal of Sports Medicine and Physical Fitness*, 45(3): 370-380.
81. ERNST, E. (1998). Does post-exercise massage treatment reduce delayed onset muscle soreness? A systematic review. *British journal of sports medicine*, 32(3): 212-214.
82. TIIDUS, P.M. (1997). Manual massage and recovery of muscle function following exercise: A literature review. *Journal of Orthopedic and Sports Physical Therapy*, 25(2): 107-112.
83. HEMMINGS, B.; SMITH, M.; GRAYDON, J. & DYSON, R. (2000). Effects of massage on physiological restoration, perceived recovery, and repeated sports performance. *British journal of sports medicine*, 34: 109-115.
84. DENWORTH, L. (2015). The social power of touch. *Scientific American Mind*, 26(4): 30-39.
85. LOKEN, L.S.; WESSBERG, J.; MORRISON, I.; MCGLONE, F. & OLAUSSON, H. (2009). Coding of pleasant touch by unmyelinated afferents in humans. *Nat Neurosci*, 12(5): 547-548.
86. MCGLONE, F.; WESSBERG, J. & OLAUSSON, H. (2014). Discriminative and affective touch: sensing and feeling. *Neuron*, 82(4): 737-755.
87. KARLSSON, J. & SALTIN, B. (1971). Diet, muscle glycogen, and endurance performance. *Journal of applied physiology*, 31(2): 203-206.
88. JEFFERS, R.; SHAVE, R; ROSS, E.; STEVENSON, E.J. & GOODALL, S. (2015). The effect of a carbohydrate mouth-rinse on neuromuscular fatigue following cycling exercise. *Applied physiology, nutrition, and metabolism*, 40(6): 557-564.
89. CLARKE, N.D.; KORNILIOS, E. & RICHARDSON, D.L. (2015). Carbohydrate and caffeine mouth rinses do not affect maximum strength and muscular endurance performance. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 29(8): 2071-2373

90. BLOMSTRAND, E.; MOLLER, K.; SECHER, N.H. & NYBO, L. (2005). Effect of carbohydrate ingestion on brain exchange of amino acids during sustained exercise in human subjects. *Acta Physiol Scand.*, 185(3): 203-209.
91. TRUDER, H.K. & WEICKER, H. (2001). Physiology and pathophysiology of the serotonergic system and its implications on mental and physical performance. Part II. *International journal of sports medicine*, 22(7): 482-497.
92. STRUDER, H.K. & WEICKER, H. (2001). Physiology and pathophysiology of the serotonergic system and its implications on mental and physical performance. Part I. *International journal of sports medicine*, 22(7):467-481.
93. IVY, J. & PORTMAN, R. (2004). *Nutrient Timing*. North Bergen, NJ: Basic Health Publications, Inc.
94. KARP, J.R.; JOHNSTON, J.D.; TECKLENBURG, S.; MICKLEBOROUGH, T.D.; FLY, A.D. & STAGER, J.M. (2006). Chocolate milk as a post-exercise recovery aid. *International journal of sport nutrition and exercise metabolism*, 16: 78-91.
95. GILSON, S.F.; SAUNDERS, M.J.; MORAN, C.W.; MOORE, R.W.; WOMACK, C.J. & TODD, M.K. (2010). Effects of chocolate milk consumption on markers of muscle recovery following soccer training: a randomized cross-over study. *Journal of the International Society of Sports Nutrition*, 7(1): Epub ahead of print.
96. OWEN, A. (2006). Chocolate milk whips Endurox in recent recovery test. *Running Research News*, 22(7): 1, 6-9.
97. WALLACE, B. & ABEL, M.G. (2010). Effects of chocolate milk on perceived exertion and muscular strength following resistance training: a pilot study. *International Journal of Fitness*, 6(1): 25-33.
98. ROY, B.D. (2008). Milk: the new sports drink? A Review. *Journal of the International Society of Sports Nutrition*, 5(15).
99. THOMAS, K.; MORRIS, P. & STEVENSON, E. (2009). Improved endurance capacity following chocolate milk consumption compared with 2 commercially available sport drinks. *Applied Physiology Nutrition and Metabolism*, 34(1): 78-82.
100. ERITH, S.; WILLIAMS, C.; STEVENSON, E.; CHAMBERLAIN, S.; CREWS, P. & RUSHBURY, I. (2006). The effect of high carbohydrate meals with different glycemic indices on recovery of performance during prolonged intermittent high-intensity shuttle running. *International journal of sport nutrition and exercise metabolism*, 16(4): 393-404.
101. SPACCAROTELLA, K.J. & ANDZEL, W. (2011). The Effects of Low Fat Chocolate Milk on Postexercise Recovery in Collegiate Athletes. *Journal of Strength & Conditioning Research*, 25(12): 3456-3460.
102. BATY, J.J.; HWANG, Z.; DING, Z. & ET AL. (2007). The effect of a carbohydrate and protein supplement on resistance exercise performance, hormonal response, and muscle damage. *Journal of Strength and Conditioning Research*, 21(2): 321-329.
103. CAMPBELL, B.; KREIDER, R.B.; ZIEGENFUSS, T. & ET AL. (2007). *International Society of Sports Nutrition position stand: protein and exercise*. *Journal of the International Society of Sports Nutrition*, 4(1): 1-7.
104. CRAMER, M.J.; DUMKE, C.L.; HAILES, W.S.; CUDDY, J.S. & RUBY, B.C. (2015). Post-exercise Glycogen Recovery and Exercise Performance is Not Significantly Different Between Fast Food and Sport Supplements. *International journal of sport nutrition and exercise metabolism*, ePub, March 26.
105. LEMYRE, P.-N. & FOURNIER, J. (2013). Psychological aspects of recovery. In: Hausswirth C, Mujika I, eds. *Recovery for Performance in Sport*. Champaign, IL: Human Kinetics, p. 43-52.
106. PARGMAN, D. (1993). Sport injuries: An overview of psychological perspectives. In: Pargman D, ed. *Psychological Bases of Sport Injuries*. Morgantown, WV: Fitness Information Technology, p. 5-13.
107. HARDY, C.J. & KELLY CRACE, R. (1993). The dimensions of social support when dealing with sport injuries. In: Pargman D, ed. *Psychological Bases of Sport Injuries*. Morgantown, WV: Fitness Information Technology, p.121-144.
108. MARCORA, S.M.; STAIANO, W. & MANNING, V. (2009). Mental fatigue impairs physical performance in humans. *Journal of applied physiology*, 106(3): 857-864.
109. ZIJLSTRA, F.R.; CROPLEY, M. & RYDSTEDT, L.W. (2014). From recovery to regulation: an attempt to reconceptualize 'recovery from work'. *Stress and health : journal of the International Society for the Investigation of Stress*, 30(3): 244-252.
110. MARCORA, S.M.; STAIANO, W. & MANNING, V. (2009). Mental fatigue impairs physical performance in humans. *Journal of applied physiology*, 106(3): 857-864.
111. SMITH, M.R.; MARCORA, S.M. & COUTTS, A.J. (2015). Mental Fatigue Impairs Intermittent Running Performance. *Medicine and science in sports and exercise*, 47(8): 1682-1690.
112. PAGEAUX, B.; MARCORA, S.M. & LEPERS, R. (2013). Prolonged mental exertion does not alter neuromuscular function of the knee extensors. *Medicine and science in sports and exercise*, 45(12): 2254-2264.
113. PAGEAUX, B.; MARCORA, S.M.; ROZAND, V. & LEPERS, R. (2015). Mental fatigue induced by prolonged self-regulation does not exacerbate central fatigue during subsequent whole-body endurance exercise. *Frontiers in human neuroscience*, 9:67.
114. HOLDEN, C. (2009). Shrinking the shrinks. *Science*, 326(5949): 25.
115. MILLER, G. (2010). Beyond DSM: Seeking a brain-based classification of mental illness. *Science*, 327: 1437.
116. HOOPER, S.L.; MACKINNON, L.T. & HOWARD, A. (1999). Physiological and psychometric variables for monitoring recovery during tapering for major competition. *Medicine and science in sports and exercise*, 31(8): 1205-1210.
117. KELLMANN, M. & KALLUS, K.W. (2001). *Recovery-stress Questionnaire for Athletes*. Champaign, IL: Human Kinetics.

118. KENTTÄ, G. & HASSMÉN, P. (2002). Underrecovery and overtraining a conceptual model. In: Kellmann M, ed. *Enhancing recovery: preventing underperformance in athletes*. Champaign, IL: Human Kinetics, p. 57-79.
119. CALDER, A. (2003). Recovery strategies for sports performance. *Olympic Coach*, 15(3): 8-11.
120. HOGG, J.M. (2002). Debriefing: a means to increasing recovery and subsequent performance. In: Kellmann M, ed. *Enhancing recovery: preventing underperformance in athletes*. Champaign, IL: Human Kinetics, p. 181-198.
121. GERBER, M.; KALAK, N.; LEMOLA, S. & ET AL. (2013). Are adolescents with high mental toughness levels more resilient against stress? *Stress and health : journal of the International Society for the Investigation of Stress*, 29(2): 164-171.
122. GUCCIARDI, D.F. (2012). Measuring mental toughness in sport: a psychometric examination of the psychological performance inventory-a and its predecessor. *Journal of personality assessment*, 94(4): 393-403.
123. HORSBURGH, V.A.; SCHERMER, J.A.; VESELKA, L. & VERNON, P.A. (2009). A behavioural genetic study of mental toughness and personality. *Personality and Individual Differences*, 46(2): 100-105.
124. WILSON, G.S. & RAGLIN, J.S. (2004). The predictive value of hardiness and optimism for the identification of past staleness in high school age male and female distance runners. *New Studies in Athletics* 19(2): 41-46.
125. SIFF, M.C. (1998). *Facts and Fallacies of Fitness*. University of Witwatersrand, Johannesburg, South Africa: Mel Siff.