

Recovery and Regeneration

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30:3; 45-56, 2015

Every competent coach knows that recovery and regeneration are the opposite but equally important sides of the training equation. The rest, healing, repair, and recharging that take place between workouts are as essential for the athlete's development and performance as what happens in the workouts themselves. But compared to training modes, loading, periodisation, etc., one senses that the modalities and techniques of recovery and regeneration have received somewhat less attention.

In fact, work in this field has been ongoing over the years and the body of scientific knowledge and practical experience is growing. If anything, the focus has become more intense recently.

For this NSA Roundtable, we asked our London-based contributor Jimson Lee, himself a coach and the founder of the website www.SpeedEndurance.com, to interview six of this field's leading figures from around the world. The aim was to get a cross-section of views on how they understand the concept of recovery and regeneration and how they apply the most well known approaches.

The result of this panel discussion can only be described as a master class, with important nuggets of wisdom on sleep, nutrition, massage, cryotherapy and many other relevant points that complement the other articles in this issue. We believe it is of high value for coaches and anyone who plays a part in performance delivery, especially at the elite level, and have therefore published the results in full as our longest Roundtable ever.

The members of the panel are:

Carlo Buzzichelli, AAS, the Director of the International Strength & Conditioning Institute in Australia.

Marco Cardinale, PhD, the Head of Sports Physiology of Aspire Academy in Doha, Qatar.

Derek Hansen, MASC, CSCS, the head strength and conditioning coach for Simon Fraser University in Vancouver, British Columbia, Canada.

Henk Kraaijenhof, a top-flight coach from the Netherlands whose well-known charges over the years have included Nelli Cooman (NED) and Merlene Ottey (JAM).

Iñigo Mujika, PhD, the author of a number of scientific and practical training oriented works including a book entitled *Recovery for Performance in Sport*.

Yusuf Omar, the founder and President of The System: Art and Science of Coaching, who is based in Toronto, Ontario Canada.

NSA *How do you define recovery and regeneration? Is it simply getting enough blood and glucose to the affected areas? Is it trying to heal the body from trauma and stress, to get ready for the next workout?*

Buzzichelli: I would define it as the process(s) taking place after physical exertion in order to restore the complete functionality of the physiological systems and the energy substrates specifically taxed by the activity.

Recovery strategies should consider all the physiological systems (the central nervous system, the endocrine system, etc.), the degree of myofibrillar damage and protein catabolism caused by the activity, the need of soft tissue therapy to control muscle tone and myofascial functionality, the restoration of energy stores, and the psychological influence. Methodologically speaking, the alternation between different physical loads within the macro and microcycles, coupled with the implementation of recovery and regeneration strategies, can highly enhance the morpho-functional adaptations to training, and the level of performance. Coaches should remember that psychological stress can also affect an athlete's response to training. The mere fact that the planned programme calls for a high-intensity training day does not mean that the coach or athlete should not adjust it, based on an athlete's current physical or emotional state. Sometimes less is more, and sometimes rest has a greater influence on adaptation than training.



Cardinale: Recovery and regeneration is a complex phenomenon determined by the interaction of various physiological systems to restore normal form and function following training or competition. In my

view, it cannot be simplified to a single outcome but has to be seen holistically. So, in order to understand it better we have to start always from the definitions. Recovery is defined as the "return" to a normal state of health. Regeneration comes from the Latin *regenerate*, which means re-create. So it cannot be reduced to a simple outcome. As training and competition affect many physiological systems and induce stress we have to consider the recovery and regeneration process as the one needed to restore form and function of the body.

Hansen: When speaking of recovery and regeneration, the key variable to examine is the amount of work being performed and whether or not it is appropriate for the athlete(s) in question. If the workload is too high, no amount of recovery will be sufficient to advance the athlete,

let alone keep them healthy. Thus, it is imperative that the amount of work or "stress" applied to the athlete is carefully prescribed. Once an appropriate workload is determined, it is important to examine the time component involved in recovery. How much time does it typically take an athlete to recover from a given session or specific training load? From there, we can identify means of speeding up the recovery process enhancing athlete readiness, as well as monitor the efficacy of various approaches. The methods used to enhance recovery can shorten the time required to fully recover, as well as enhance the magnitude of super-compensation achieved. A successful recovery and regeneration programme should not simply be about returning athletes to homeostasis more quickly, but vaulting them to new levels of performance. Thus, the recovery and regeneration programme must be well integrated with all aspects of training and closely monitored to ensure improvements take place in a timely manner.

Kraaijenhof: They are about the psychology of adaptation and the proper manipulation of the biochemical, hormonal, and physiological systems important for the development of performance. These systems do not function in isolation. They react and influence each other to various degrees in response to the stimulus of training. The main question is what needs to be recovered, since recovery will happen automatically. If one trains, they get tired or sore, they will recover if they take the time. We have to ask: can I enhance recovery (= recover more) and/or accelerate recovery (= recover faster)? If you work out twice a week, you barely need to speed up recovery, however, if you train twice a day, the limitation becomes not the systems that recover fast, but those that recover slow, causing accumulative or chronic wear-and-tear or depletion.

Mujika: I consider recovery a key part of the training process. In fact, I don't understand training as a single entity, but as a cycle based on both the time to train and recover in order to adapt to a given training bout. From that perspective, I would say that recovery is the time needed for an athlete to re-establish homeostasis and assimilate the work done. This is re-

lated with but not synonymous to the concept of proactive recovery, which are the strategies we may put in place to try to accelerate or optimise the recovery and adaptation processes.

Omar: Recovery and regeneration are the processes that are available for the athlete to diminish the physical, mental, and emotional stressors affecting performance. They are multi-factorial, entailing several conditioning and non-invasive elements aimed at minimising the stressors that define the athlete's actual ability versus potential ability. These are conscious, systematic approaches that I believe take into consideration Selye's *General Adaptation Syndrome* (GAS). Since the body undergoes a specific set of hormonal and CNS responses (short-term) and adaptations (long-term) after being exposed to these stressors, proper recovery and regeneration tries to minimise this insult and maximise performance. To accomplish this, major influencers have to be addressed such as *proper planning and loading, sequencing of training elements* (speed/speed-endurance, strength etc.), *intensity of training loads* (i.e., use of lower intensities for active recovery), *hydration*, and *proper rest intervals*. There are also several modalities such as massage, osteopathy, stretching (i.e., microStretching), homeopathic remedies, micro-current, EMS, contrast sauna/baths, as well as processes that aid in the proper sleep of the athlete. Sleep is very important for the deeper the sleep the better the recovery.

NSA *Let's talk about active strategies and timing, and the term "active recovery". For example, after a hard CNS speed workout, how much time is required before the next hard workout? Many coaches like to use tempo running (i.e. speeds of less than 70% max) to aid recovery.*

Buzzichelli: With proper active recovery the intensity and volume of the training stimulus is very important. Hard speed training requires at least 48 hours before another workout of the same type, but a stimulating workout, characterised by high intensity low volume, requiring far less time (6 – 24 hours) since the residual fatigue is minimal. In comparison, during a

competition where a sprinter does several 100 and 200m races, five to seven days of recovery would be needed. Active recovery should consist of moderate aerobic exercise, which will help with eliminating waste products (i.e., lactic acid). Within the first ten minutes of such activity, 62% of lactic acid is removed and a further 26% is removed in the following 10 minutes. In addition to the aerobic activity, stretching exercises should be introduced. This combination aids in the removal of metabolites reduces body temperature, heart rate, blood pressure, mental stress, stress on the central nervous system, and cortisol levels. High levels of cortisol may disturb sleep up to 24 hours thereby delaying the recovery process.

Cardinale: First of all I do not agree with the term CNS speed workout. The CNS is involved also when you walk at low speed, so we should stop using such terminology. Before answering any question about recovery we should ask the question recovery from what? Active recovery strategies are mainly used to lower heart rate, increase the rate of lactate clearance, and regulate blood flow in the exercise limbs. The effects of such interventions are very short term and have a small influence over muscle perfusion and skeletal muscle metabolism. They definitively affect the cardiovascular system but have limited effects on tendons and, despite the perceived benefits, the evidence is a bit scant on the extent of their effectiveness on the CNS.



Kraaijenhof: With active recovery one needs to be wary that though it may be beneficial for the recovery of one system, it may place a physiological load on another. For instance, repeated sprints for weeks on a hard track places great stress on the metatarsal bones and the Achilles tendon, which continue to be stressed with tempo training for recovery. Is it any wonder why stress fractures or inflammation of the Achilles tendon linger on even with active recovery methods? The key point here is don't underestimate the impact of a recovery workout and be aware of negative interference.

Hansen: I am a big proponent of the concept of recovery being an “active” process. Doing “nothing” is not an acceptable means of facilitating recovery. The type, intensity, and arrangement of exercise can be a critical means of allowing recovery to effect a positive change. Low intensity work significantly enhances the recovery process giving athletes a greater feeling of well-being, while maintaining or improving their general fitness capabilities. All of this work must be planned into the overall programme, moving between high intensity training sessions and low intensity recovery sessions seamlessly, with passive recovery methods used strategically to facilitate super-compensation following more aggressive training sessions.



Mujika: Although we can establish some general recovery times after training sessions targeting specific physiological systems, I believe that recovery times, and methods, are individualistic. Some athletes may thrive on high intensity training while struggling with high volume loads, whereas the opposite is true for others. Athletes may recover well from a hard intense workout using low intensity training, whereas others would rather have complete rest. Another factor to keep in mind in your example is what event the athlete is training for: is he or she a pure sprinter, thrower, or a middle distance runner? This would determine the training content included in the athlete’s programme, and will of course impact on recovery times and methods. We also need to consider the time of the season: are we in a phase in which adaptation is the most important goal? Are we in the competitive period when it is all about performing and recovering? These are factors that make recovery individualisation and periodisation so important!

Omar: In my opinion for the type of training you mention, amateur athletes may require 48 to 72 hours, with elite athletes requiring as much as 48 but as low as 24 hours. However, with proper application of the correct regenerative methods, and the appropriate dose of

intensity and volume, the time required may be substantially diminished. In terms of actual active recovery methods, I am a big proponent of easy pool workouts to accelerate regeneration. If accessibility is an issue, running on heavily cushioned grass or any other surface would be my second choice. If all else fails, sometimes a walk through the woods might be just what the doctor ordered. It is important to keep in mind that active recovery strategies are also determined by the recovery rate(s) of certain parts of the body (i.e., larger versus smaller muscle groups). The larger ones being important for gross motor movement with the smaller ones pertaining to precision. Further, the acquisition of a new skill is another potential stressor that many coaches and athletes do not realise places great stress on the body. Both extrinsic and intrinsic learning of skills require physical adaptation and neural patterning which may take up to two or three weeks to become fully entrenched in the athlete’s movement. It is important to realise that roughly 3000 to 5000 repetitions of a skill are required before it progresses from a forebrain activity to a hindbrain, with another 3000 to 5000 repetitions to transfer the skill from a hindbrain activity to a spinal loop and eventually a fascial loop.

NSA *Let’s talk about passive strategies. Soft tissue massage, myofascial release and self-myofascial release (i.e. foam rollers) are popular “old fashioned” strategies. How much is overkill? When should you not massage? Isn’t having a certain amount of “muscle tone” good for the body?*

Buzzichelli: Massage and myofascial release are important tools for recovery, performance enhancement, and injury prevention. Massage increases blood circulation and lymphatic drainage, providing oxygenated blood to the massaged area, while moving extravascular fluid into the lymph vessels and subsequently into the circulatory system. A process described as a cleaning-out action. Both techniques are concerned with muscle tone and myofascial degree of freedom. Muscle tone, low or high, affects the body and ultimately performance. Low tone, a result of a relaxed state, hinders the excitability of muscle, reduc-

ing proprioception. On the other hand, a high tone is responsible for causing very tense muscle affecting the removal and the flushing out of metabolites, resulting in greater fatigue. Both can lead to joint and muscle issues. Myofascial release helps to relieve muscle tension allowing for greater freedom and range of movement, which is very important for peak performance in speed and power sports. Therefore, for optimal performance a massage therapist needs to be aware of the ideal tension within the athlete's muscle(s), a balance between a supple and tense. Deep tissue massage should be planned for the day before an intense session or two to three days before competition. Myofascial release techniques can complement massage and be used on the day before competition or even on the very day of competition. Personally, I am not a big believer in self-myofascial release, as it does not get close to the effect of a good practitioner. It is practical and efficient if you think, for instance, of a team sport setting with a limited budget, but the effectiveness is greatly reduced.

Cardinale: I keep going back to the question: recovery from what? A recovery modality might be good for some aspects and not so good for others. Soft tissue massage is very popular with athletes but the scientific evidence for its effectiveness is debatable. Few studies have been conducted with athletes and there are some equivocal results. In general massage has a lot of positive evident and perceived effects on anxiety, pain perception and possibly heart rate, but the evidence in restoring neuromuscular function is scant. In my experience, perception of the effectiveness of massage makes a big change on the perceived muscle soreness by athletes. Data from my colleague Professor Christian Cook suggested that different massage therapists produce different effects what have nothing to do with their massage skills, but more with their appearance and perceived effectiveness. For sure there is a "feel good" factor that cannot be underestimated, and to some extent some placebo effect, which induces athletes to believe they are recovering. Acutely massage, can have a negative influence on force production but, again, we don't know if it is true for a large sample size

and how long it lasts. Massage before a competition might be good for endurance events, not so good for jumps and sprints. But the evidence is not there. As for the effects on lactate clearance etc., there is some evidence against this assumption so, maybe it is not good for the muscle after all! Foam rollers are now becoming more and more popular. Again research is catching up, recent work seems to suggest that using a foam roller reduces arterial stiffness and improves vascular endothelial function as compared to doing nothing following a workout but I think there is a need for more studies to really see if this mechanical stimulation has any real physiological value and if it is better than anything else. So in my view, sometimes there is a place for such interventions, mostly to favour the "feel good" factor and improve the perception of recovery, provided practitioners and coaches involved in delivering such modalities avoid providing pseudo-scientific information and do not attribute to such modalities effects which are not there.

Hansen: All of these passive strategies can help to improve an athlete's feeling of wellness and readiness. Some are proven by research to have a significant effect, while others have met with good anecdotal success. Even if some of these methods act as a placebo, I don't have a problem with integrating them into the overall training and recovery approach. I think where things can go off the rails is when these methods are given more credence than the training or programming planning itself. No matter how skilled your massage therapist or you chiropractor are, if your training is ill conceived, you will not have success. I find it interesting when athletes praise their physical therapist for all of their great work, when I wonder why the athlete has been dealing with injuries in the first place? In many cases, perhaps athletes can suffer from too much of a good thing.

Kraaijenhof: Most manual therapies are overkill, having a huge placebo effect: a ritual of getting attention, the familiarity of being taken care of, and relaxation. Some athletes enjoy them, while others having never been treated do just as well. It might become addictive to the extent that athletes THINK they won't do

well or will get injured if they do not get regular treatment. No clear linear relationship exists between the amount of time spent with a therapist and the decrease of injury and increase in performance. Coaches should always monitor the individual athlete's responses to treatment and not to always believe them when they say they "feel so much better". Injuries in explosive events can also occur from low muscle tone. Therapies always change the subtle afferent input, so how do you know what is optimal?

Mujika: The problem with massage is the lack of scientific evidence to back it up. Doing proper research about massage is really difficult, as no massage therapist will ever perform two identical treatments, let alone different therapists performing identical treatments. Nevertheless, there is evidence indicating positive effects of massage at a psychological level, and this should have a positive impact on performance. My personal approach to massage is to allow an athlete to decide to have a massage or not. If it contributes to their performance, fantastic, otherwise I believe it to be a personal thing. I would like to emphasise that I am referring to massage as a recovery tool here, not to soft tissue therapy, which may be needed to solve a problem that may interfere with proper technique and/or degenerate and induce a more serious injury.

Omar: In my opinion "do what works & not what is said". It is important to realise that what works for one athlete may not for another. That said, what is most important for choosing an appropriate passive strategy modality (i.e., massage, EMS, stretching etc) is the degree of fatigue and overtraining. All these strategies are tools in the toolbox. Sometimes a two-hour flush massage after an intense speed session might be warranted, while other times use of a deep tissue, to eliminate the "knots" in the muscle, might be what is needed. The issue when using massage becomes the depth of the pressure applied, the duration, the area of the body and how much of it is massaged. Skilled hands, through experience, can determine how much tonus is required for conditioning vs. helping the athlete attain a completely relaxed state. A certain amount of tonus

is required for performance, which will require keen observation from both the therapist and the athlete. Another method that I have used is microStretching®, which can be viewed as a form of "massage". If it is applied in the appropriate manner, it can help decrease inflammation and the intense tonal state of the muscle post training and competition. This will help the athlete recover and regenerate, thus preparing them for further training.

NSA *Electrical muscle stimulation is popular in Europe but not in North America. Why aren't more coaches and athletes using EMS?*



Buzzichelli: Although I own several EMS units and have been using them for almost two decades, I believe the very concept underlying EMS, excluding the nervous system to elicit muscle contraction, has very limited applications for the athletic population. Such applications would be: maintaining or restoring muscle mass in a immobilised limb via high volume of isometric contractions, using very low frequencies (below 9 Hz) to induce systemic relaxation, and using very high frequencies (TENS) to reset nociceptors.

Cardinale: I think it went out of fashion a few years ago and has been substituted by other modalities. Joking aside, there is an element of marketing and popularity for each modality implemented. The review published in 2011 by Babault et al. is a good reading for coaches and clarifies its possible use in recovery. However I am afraid that even there the evidence is not terribly strong.

Hansen: Simply put, there has not been enough information provided to average consumers to give them the knowledge and confidence to use electrical stimulation. It has been the sole domain of physical therapists and, in many cases, the majority of them do not know how to maximise the potential, particularly for athlete recovery. Research has demonstrated that electrical stimulation can not only enhance strength, power and speed, but also improve

many aspects of recovery and regeneration. However, like any training and recovery tool, the user has to possess some degree of skill in order to benefit from it. EMS is not different from a barbell in that respect. Until more coaches and athletes understand how to maximise the use of EMS for their training and recovery, we will not see more widespread use.

Kraaijenhof: EMS is like a dolphin, it can be under water and all of a sudden it surfaces again as “new and improved” or “developed by NASA”. It hardly has a value for most athletes, since it is only training for one or a few muscle groups and has a recruitment pattern that is far from specific. But I still find it very valuable in conjunction with or during active resistance exercise, in case of injuries as a temporary tool for maintaining or improving strength, for training muscle groups that are hard to train (i.e., foot muscles), or while travelling (e.g. intercontinental air travel) to maintain muscle tone.

Mujika: Like massage, the evidence supporting EMS as a recovery tool is really weak, and that may be a reason why it is popular in some places but not in others. It may simply be a matter of local trends.

Omar: The issues around the popularity of EMS at any time or in any place are:

- Cost of the apparatus
- Familiarity of use
- Practicality of use
- Safety & liability
- Which units are the best to purchase?
- Personal experience by the coach
- Fear and apprehension on the part of both the coach & athlete (i.e. it can be somewhat daunting to have parts of your body contract involuntarily)

NSA *Cryotherapy seems to make headlines these days. What happened to the old-fashioned sauna, contrast baths (hot/cold) and ice baths. Are they still a good idea?*

Buzzichelli: There is emerging science that ice bath, as well as cryotherapy, reduce the adaptations to training. In fact, post-training tis-

suess inflammation is a metabolic trace that must not be completely dumped. This, in actuality, applies to all the strategies that tend to reduce the metabolic traces of training, such as, for instance, anti-oxidant supplementation. For this reason, cryotherapy and ice baths are a good choice when recovery is the priority over training adaptations in the competitive phase. Contrast baths, on the other hand, can be planned all year, as they mainly increase blood flow from the skin to the organs and aid in the elimination of waste products from the muscles. Athletes should alternate 30 to 60 seconds of hot water with 30 to 60 seconds of cold water for two or three sets. Of course, this technique takes a little getting used to, but it is extremely effective.

Cardinale: We have just finished a review on cold water immersion and contrast water therapy in young athletes that should be published soon and the effects are pretty small in many physiological systems (acutely). However recent meta-analyses on adults suggest some degree of benefit with regards to delayed onset of muscle soreness and perception of pain following intense exercise. The evidence on sauna is really scant. Some recent work seems to suggest some positive effects of sauna on oxidative status and recovery from exercise. The studies were performed in healthy individuals but not on athletes so we really do not know if the same holds true for an athletic population. For sure more studies are needed. With this modality, dehydration can be an issue.



Hansen: I believe the cryosaunas are achieving results because the technology produces a significant stimulus and a profound response from the body due to the extremely low temperatures that an individual experiences, albeit over short durations. Other conventional methods of hot and cold therapy can still be effective if implemented in a well-timed, integrated fashion. I do feel that many of these conventional approaches are over-used in many instances, with the impact lessening as the body adapts to the relatively smaller temperature changes compared with cryosaunas.

Kraaijenhof: Recent research shows that by inhibiting the inflammatory process cryotherapy might also inhibit the demanded training response, since inflammation is basically a repair process and a stimulus for the training effect. The tissue-weakening effects of e.g. cortisol and anti-inflammatory medication are well-known. For me, I distinguish between two kinds of recovery: the recovery before the next workouts where I want the athlete to recover to the extent that a good quality of the workout is guaranteed, and a long-term recovery that prevents the accumulation or wear-and-tear or depletion. In this case I don't want to block a certain level of inflammation (or discomfort or fatigue), to guarantee a maximum training effect. But on the other hand, there is the recovery before e.g. the finals of a World Championship for explosive event(s). Now I don't care about a long-term training effect anymore, but about immediate conditions for delivering and optimal performance without pain, discomfort or fatigue, so in this case I will use mainly local cryotherapy or other measures that create optimal conditions for the athlete to perform at his/her best. The problem is that we seldom distinguish between the short- and long-term effects of recovery measures, since the effects could be different or even opposite.

Mujika: You are mentioning different strategies with totally different effects that may be used for very different reasons! Whole body cryotherapy has been popular in Europe for years, particularly for contact sport athletes such as rugby players suffering severe inflammatory processes. The main problem is a lack of evidence about its effectiveness to enhance recovery and adaptation in elite athletes. Research efforts now being made at INSEP in Paris are getting some interesting results on recovery after muscle damage induced by eccentric overload exercise. The recovery experts of the Australian Institute of Sport (AIS) have been very active investigating ice baths and contrast water therapy for a decade now. Although there are recovery benefits in the short-term and such a strategy may improve the quality of sleep after hard training sessions, the jury is still out about the impact of ice baths on long-term training adaptations, with some

research indicating that chronic use of ice baths may blunt adaptations. As for sauna, it's something I use not as a recovery tool, but as a tool to induce additional stress and hopefully additional adaptation with endurance athletes.



Omar: Not in favour of ice baths, unless dealing with contact injury sports, and even then, the question remains if you want additional CNS sympathetic response in an athlete whose system has already been stimulated from the trauma. One might be better off using a small bucket, with some Epsom salts/baking soda or using products like "PRO-ICE" to "freeze" specific body parts (e.g. low back, lower/upper legs etc.). Contrast baths with a dry sauna are perhaps maybe better suited for most athletes. Now, if one can combine this with microStretching, a gentle use of a massage stick, gentle foam rolling, or use of a small ball (i.e., tennis, lacrosse etc.) it might complement the use of contrast baths. Areas that could be addressed are: hamstring insertion, ITB, glutes, upper back, quad tendon at the insertion of the ASIS, SI ligament. Besides contrast baths, I also use techniques such as Gu-Sha (a.k.a., Graston Technique) for specific areas of the body, micro-current targeting tissue healing and CNS up-down regulation, the Chi Machine (oscillation device for lymphatic drainage), as well as massage in combination with cranial – auricular therapy, and hand & Foot reflexology. The combination of these techniques ensures that both the autonomic and somatic systems are treated, which is very important for proper recovery and regeneration.

NSA *Sleep (and to some extent, naps) is probably the cheapest option out there, yet so many athletes neglect it. Is there an optimal sleep cycle? Can certain hormones such as human growth hormone (HGH) or testosterone be released in the sleep cycle?*

Buzzichelli: Complete rest is perhaps the one necessity that all athletes have in common. To function at full capacity, most athletes require about 10 hours of sleep per day, a por-

tion of which usually takes the form of naps. Athletes should also have regular sleeping habits and be in bed no later than 11:00 p.m. In addition, practicing relaxation techniques prior to bedtime can put the athlete's mind in a more restful state. Scientific research shows that there is a strict correlation between the amount of sleep and testosterone levels. Peak release of growth hormone happens after the onset of sleep (slow wave sleep – stage III and IV). Disruption of sleep can negatively affect the total daily release of growth hormone. Recently, mobile phone applications (i.e., SleepAsAndroid), are being used to effectively monitor and adjust athlete sleep patterns.

Cardinale: Sleep is very important not only for recovery but also to prepare best for training and competitions. Lack of sleep has been shown to impair physical and mental function, so sleep as a recovery intervention is a must! The optimal sleep cycle is to sleep when you are due to sleep to maintain normal circadian rhythm. The main aspects for improving sleep are the diet and the sleep environment. Everybody talks about sleep but very few try to improve the sleeping environment of an athlete. For example, how many place an effort in making sure the athlete has access to the best mattress, pillow, covers, and sheets? How many check if it is possible to have a dark, clean, quiet room in which the athlete sleeps in? These are the basics for good sleep. Many, unfortunately, are worried and distracted by gadgets and gizmos and are looking for supplements when sometimes just having good basic routines and environment can make a big difference. Hormones have pulsatility that makes them peak in the morning. What we know is that lack of sleep definitely lowers morning testosterone levels. HGH values are also affected by lack of sleep. In the context of training and/or competition performance, however, we need to do more to understand what this means.

Hansen: The whole sleep discussion is very similar to the talk around nutrition. It all comes down to managing human behaviour. We all know that we should eat better and improve our sleep habits. The challenge is in

actually getting it done and staying disciplined with it. It comes down to creating consistent habits around your sleep and the preparation for sleep. Conversely, I believe that over-sleeping can also be a problem for many athletes. As we mentioned in the active recovery discussion, some degree of movement and activity is often better than no activity when it comes to recovery and regeneration. There may be an optimal minimum dose of sleep that individual athletes require, but I would also point out that staying in bed too long is problematic. Night time sleep is optimal, but athletes may also require short naps throughout the day, particularly when workloads are high or they travel through several time zones.

Kraaijenhof: Adequate sleep duration and quality are irreplaceable for athletes since they are necessary for the recovery and repair of all physiological systems. Neglecting sleep is the easiest thing to do nowadays, since there are so many interesting and exciting things to do while awake: computer games, Facebook, Twitter and other social media. These are perfect sleep destroyers. Sometimes these distractions may help athletes from anticipatory competition stress, but at the price of mental overload and lack of sleep. Now the smart athlete, looking at his/her opponents will know they can get a benefit from sleeping adequately. And at world-class level, even a small advantage can make a huge difference. Sleep is so important that we spend 1/3 of our lives sleeping. If it did not serve an evolutionary survival purpose, we would be able to sleep only 2-3 hours a day without paying a price.

Mujika: There's no doubt that sleep is the most important recovery method of all. No recovery strategy is powerful enough to substitute proper sleep. A restorative relationship has been suggested between sleep and the immune, endocrine, metabolic, and nervous systems. Sleep also plays a key role in learning, memory, and synaptic plasticity. Thus, it is clear that sleep is absolutely crucial for proper adaptation to training. I would recommend all coaches to read Shona Halson's 2008 paper "Nutrition, Sleep, and Recovery".

Omar: Adhering to a consistent sleeping schedule is very important, especially for athletes with other commitments such as school, family life, peer interactions, etc. These stressors will affect their true potential, since their deep sleep will be interrupted. It has been said that Bruce Lee used to get four to five hours of sleep each night, with most of it in the deep REM state. The issue sometimes is not the amount of sleep, but the quality of sleep. Athletes need to develop proper “sleep hygiene” to facilitate a higher quality of sleep. Preparing their bedroom by removing stimulants such as cell-phones, tablets and other implements requiring their attention, besides having fresh air and a clean room, are a few things they need to consider. Adding specific vitamin and mineral supplements, herbs, and homeopathic remedies might help. Carb ingestion before bed may help to produce deeper states of sleep as well. I teach athletes specific auricular therapy points and some cranial work that has helped them to attain deeper states of sleep. This may be due to a decrease in the sympathetic nervous system. With the subsequent calming of the CNS this potentially enhances an anabolic hormone production.

NSA *Static stretching and restoring range of motion is another inexpensive way to promote healing and trauma. Where can this fit in the athlete's routine?*

Buzzichelli: In the sport community there has been a knee-jerk reaction to the scientific literature on static stretching and power loss that came out in the late 90's and early 2000's. Some coaches have gone so far to exclude static stretching all together. In 2000 and 2001 I interned with Dan Pfaff at the University of Texas in Austin, where I had the chance to train with the likes of Donovan Bailey, Glenroy Gilbert, and Obadele Thompson. Our warm-up would include static stretching after jogging two laps, yet, by the time we would start sprinting circa 40 minutes would have passed. That is the reason why I did not overreact to the scientific literature on static stretching and power loss, as I knew by experience that the power output inhibition is only transitory and would dissipate during a long enough warm-

up routine. Certainly, you don't want to stretch the agonist muscles right before any strength, power or speed activity but, in my opinion, you can plan the static stretching after the general warm-up as well as at the end of the session.

Cardinale: For sure, but rarely before sprints or jumps if the stretching is extensive. There is time and space for this intervention but again I come back to the question: recovery from what? If the aim is to restore range of motion absolutely yes, if blood flow is the target of the intervention there are definitively better ways.

Hansen: Static stretching has received bad publicity in the last decade with all the studies demonstrating losses in power output and strength prior to exercise. Sleeping immediately prior to intense exercise is also a detriment to performance, but people are not telling us not to sleep. Like any recovery and regeneration method, if managed properly, static stretching can be a very valuable tool for lengthening muscle, reducing muscle tone, promoting a parasympathetic response and enhancing circulatory mechanism. My experience with microStretching – a passive method of static stretching that is precisely applied to various key muscle groups – has been very valuable in improving athlete readiness between intense bouts of exercise, particularly for professional athletes with significant travel and competitions demands. However, good stretching is a skill that must be taught to both athletes and coaches. Foam rolling is a self-applied soft-tissue technique that can be rather imprecise and can do more damage than good. I've seen athletes inflict bruising rolling sessions on themselves because they have not been educated as to how to use the method properly. The same goes for static stretching. When implemented properly, the results can be profound in terms of athlete recovery and regeneration.

Kraaijenhof: One of my athletes broke a world record without one stride of warming-up or one second of stretching! It depends on the event, in hurdling or javelin, a large range of motion is more important than in running

5000m. I also see the importance of stretching in the light of mental preparation for training or competition, a routine that allows the athlete to regulate his/her arousal level. Stretching definitely also changes the afferent input, a lot of neural signals are going to the brain, probably not specifically preparing for the coming explosive action. As a matter of fact, static stretching prior to explosive events diminishes the development of explosive strength. We use stretching when the lack of ROM is limiting performance or increasing the risk of injury.

Mujika: I don't rate static stretching as a recovery strategy at all. I consider it a method among others to train an athlete's range of motion, which may sometimes be needed to optimize performance and/or avoid injury by overcoming a limitation the athlete may have.

Omar: I think all athletes should at least engage in some microStretching before bed, as it has been shown to calm down the CNS. Other times, it can be used post workout, during tempo sessions or as a feeder session by itself.

NSA *Nutrition, especially the post-workout recovery drinks, is a billion dollar business. Is the 4:1 carb to protein ratio really the best method of recovery? Does timing of nutrients really matter?*

Buzzichelli: In recent years attention has been focused on what has been called "peri-workout nutrition", nutrition during the hours immediately pre-, during, and post-exercise. This has resulted in the International Society of Sports suggesting that a special post-workout nutrition strategy may increase muscle recovery and adaptation to training. Training causes a strong disturbance of the body's homeostasis. Each muscular status – energy production and substrate restoration, protein breakdown, and synthesis – requires a particular intake of macronutrients (carbohydrate, protein, and fat). Proper nutrition and timing may accelerate and amplify the body's adaptation. For athletes training three to four times per week, post-workout nutrition may not play a big role compared to the overall daily nutrient intake.

However, for competitive athletes, training five to 13 times a week, post-workout nutrition plays an important role. With regard to protein ratio, the 4:1 carbohydrates to protein might be advisable for high volume glycolytic workouts, but for alactic sessions it could be as low as 1:1 or 0.5:1. Exchanging experiences with other coaches, we found that a 2:1 ratio can have detrimental effects on body composition if the workout volume is not high enough, like during the competitive phase. Keep in mind that you want to use very high glycaemic index carbohydrate sources such as Vitargo S2 for the post-workout shake, as well as "fast" protein (e.g., whey isolate or, even better, hydrolysed whey) as the di- and tripeptides of hydrolysed protein are absorbed faster than free-form amino acids, which elicit a greater insulinogenic response. Recovery and adaptation can be enhanced by including specific amino acids (e.g., L-glutamine, taurine, and L-leucine) and peptides (e.g., creatine) depending on the training objectives.

Cardinale: Yes, athletes have different needs. I am not sure from where this ratio comes. Many studies have now suggested that protein intake during and immediately following exercise has a positive influence on muscle protein synthesis. Work done by Professor Stuart Phillips and Kevin Tipton are must-reads for coaches and sports scientists. They suggest that whey protein and casein have beneficial effects. But, of course, protein throughout the diet has great importance. A lot of recently published work on flavoured milk supports its use as well as normal milk. So, athletes should avoid spending a lot of money and running into the risks of contaminated supplements and maybe sort out their diets and drink milk or flavoured milk. This can do a lot of good to their pockets and reduce risks of utilising contaminated supplements.

Hansen: Nutritional supplementation is a big business. Are we over-thinking and over-marketing? Perhaps. I hate to go back to the sleep discussion, but I see many parallels. A bad sleep can wreak havoc on an athlete's readiness, but can a good sleep provide enhanced benefits? I'm not certain. Similarly, a

poor diet can rob an athlete of energy, create stomach distress, disturb mood and negatively impact tissue repair. However, is a good well balanced affordable diet less beneficial than an organic food-based diet supported by expensive supplements? From my experience, I can't say that the more expensive approach will yield faster times, higher jumps and farther throws. As with many of the methods discussed in this roundtable, I think we are always striving to attain minimum standards of excellence for physical therapy, sleep, diet, hydration, stretching and use of modalities. Will one of these methods in abundance vault an athlete to the top of the podium? The answer is, "Not likely." But a comprehensive approach to recovery and regeneration as a whole – combined with a well-planned training programme – will yield the best possible results.

Kraaijenhof: Nutrition is one of the most complex subjects. The hundreds of different bioactive chemicals from food and supplements interact in different ways with the thousands of biochemical processes; and this on an individual basis. One person's perfect food might be another's poison! Food is more than calories or energy, food also represent information. Food is related psychological beliefs (forbidden foods) and even social values (eating alone or with a group or friends).

Mujika: Recovery nutrition is a whole world, so I'd rather skip this one!

Omar: Rumour has it that Usain Bolt ate at a local McDonalds during the Beijing Olympics, for fear of possible food contamination and di-

gestive compatibility of the local fair that was being served at the Olympic Village. I would really like to find out if this is true. But my point is that nutrition is unique to the athlete. In general terms, post-training carb intake can range from 1:1 to 1:6. The higher ratio for would be for carb loading and for an individual who is not carb-sensitive and has a body fat percentage of less than 8%. The lower ratio would best suit someone whose body fat is over 15% and is insulin sensitive (i.e. cannot process carbs efficiently). High glycaemic load carbs might be best administered as a post-workout dietary addition. Again, this may depend upon insulin sensitivity and percent body fat, with the higher ratio to be best used with an athlete that favours a lower percent of body fat. Otherwise, throughout the day, low glycaemic carbs should be used. The idea is "you have to earn your carbs." Another important point concerns the psychology of food, and that is to "*not make food ingestion clinical*" so as to take out the enjoyment of the experience of eating. There are many factors that contribute to food absorption, namely perceived stress (i.e. psycho-social). So even if one may obtain the "exact amount," one may not absorb all of it. In fact, a good 10 to 30% of the food one eats, is used just to break down the food! So counting calories as a practice may or may not work. This again depends upon the context in which it is used. For example, counting calories for an individual who is over 15 to 18% may not work, vs. a body builder who is trying to get down to 4% or less. Therefore, nutrition plays a far greater role with athletes who are: over-fat, dehydrated, under-muscled or under-performing, otherwise if all things are good then "don't try to fix it."