How to avoid

OVERTRAINING

A SPECIAL REPORT FROM

PEAK PERFORMANCE

The research newsletter on stamina, strength and fitness

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From the editor

Successful athletes are constantly walking a tightrope. One the one hand, you need to train with sufficient intensity, duration and frequency to stimulate the maximum possible gains in performance. But there's a huge potential downside; train too hard without sufficient recovery and the nightmare of overtraining can strike, scuppering even the best-laid plans.

Overtraining can produce a wide array of undesirable and destructive symptoms including physical and mental fatigue, apathy, depression, weight loss, increased incidence of injury and illness and long-term burn out. Even more worryingly, research shows it's all too easy to stray across the line from peak condition into overtraining, which is why understanding its causes and ensuring you don't fall into the overtraining trap is vital for anyone who is serious about their performance.

The good news is that in recent years, scientists have developed a far better understanding of the condition of overtraining and more importantly, a number of practical tools to monitor training load to avoid the overtraining trap altogether. In this special report, we explain what overtraining is and how you can optimise your lifestyle to minimise overtraining risks. We also introduce you to some valuable and practical tools, which will help you to properly monitor your training loads and physiological responses and then adapt your training routine accordingly to ensure that you stay firmly planted on that tightrope and in tip-top condition!

Andrew Hamilton,
BSc Hons MRSC ACSM,
Editor

Strategies to ward off overtraining by dealing with stress from all sources

At a glance

- The causes of overtraining are outlined and the link between overtraining and recovery explained;
- Strategies for enhancing amotional, physical and cognitive recovery are given to help reduce overtraining risk.

The simple physiological equation employed by most coaches is this: training-plus-recovery-equals-adaptation. But while there are literally hundreds of ways of measuring training (eg sets, reps, load, volume, time and intensity) and a similar number for measuring adaptation (game performance, lactate threshold, heart rate, speed, power etc), how many coaches take the risk of overtraining seriously enough to measure or prescribe a recovery programme, asks James Marshall.

The evidence is that **recovery** is hugely important for athletes. Of 298 US athletes who participated in a survey after competing in the 1996 Atlanta Olympic Games, 35 (12%) said that the number one coaching decision that affected their performance was 'overtraining/ not getting enough rest' (1). In fact, it has been reported that athletes are often fitter on the plane home than en route to a competition, simply because of the rest days they have enjoyed after the event!

Recovery is not just the absence of activity; it can also mean an enhancement of activity, such as stretching, or a change of activity, such as swimming instead of running. A coach may assume that if an athlete is not training he or she is recovering,

Jargonbuster

Recovery
A well-planned activity that matches the situational needs of an athlete in rest and results in regaining an optimal performance state [5]

Cognitive
Relating to intellectual faculties of knowing, thinking or perceiving

but this may not be the case, and athletes may need a specific programme to help accelerate the recovery process.

The problem is that athletes prefer to focus on what they do best – training – and getting them to focus on recovery can be difficult. Indeed, if recovery sessions are not supervised, athletes may try to slip in extra sessions in order to 'gain an edge'. Thus, coaches need to monitor as well as prescribe their athletes' recovery programmes.

Prevention is better than the cure

Careful planning of the training programme is a key factor in preventing overtraining. External factors may have an adverse influence on an athlete's well-being, leading to underperformance, but at least the coach should be aware of some simple precepts that have been shown to work. Table 1, below, offers a succinct summary of what *not* to do.

Monotony of training can be a real challenge for an athlete, especially if he/she is in a full time squad or team and has to see the same faces at the same place every day. In such situations, a coach can maintain intensity and quality by ensuring a small change in the routine every week. This could be a change in environment – *eg* taking the team onto a track or beach for runs instead of a pitch; it could be a change of personnel – *eg* getting one of the players or assistant coaches to take a session once a week; or it could be a change of drills – basketball or five-a-side soccer being good alternative conditioning games for rugby players, for example. This sort of variation depends on advance

Table 1: how to overtrain

1. No rest days
2. No regeneration week every 2-3 weeks
3. Monotonous training programmes
4. More than 3 hours' training a day
5. More than 30% training load increase in a week
6. No alternation of hard/easy days [2,3]

planning and should be maintained even during a losing streak.

If the training environment is a cause of stress, the athlete needs to take a break from this environment. Coaches like to talk about 'team building' and 'team players', which is great on the pitch, but not every player wants to spend 24 hours a day with his team mates. A good coach will recognise the individual needs of players in terms of both training and recovery. Some players need the team environment and don't like to be left on their own, but allowing some discretionary time in training camps allows players some space to 'do their own thing' to suit their own needs.

A break away from a coach, however inspiring, is also a good thing since it allows athletes to recover emotionally and mentally from the stress of training. However, the coach needs to have confidence that his athletes are responsible and will not engage in silly activities like bungee jumping on the day before a competition!

A complete break from sport is a necessity every year, although this is not always easy in sports with long seasons, such as football and rugby, which impose high physical demands on their players and operate within competitive league structures, with the added problems of cup matches and representative matches.

This break can take the form of an annual vacation, but should not involve an additional source of stress. Having two weeks away from the sport to sit university exams, for example, will not allow for effective recovery. And if your holiday includes long-haul travel, with the additional complication of overcoming jet lag, two weeks may not be enough.

Becoming self-aware

An athlete experiences stress in physical, mental and emotional forms, and different recovery strategies are needed to address each of these areas. However, you must be sufficiently self-aware to pinpoint the real source of stress [(4)].

For example, on returning home after a day at the office, you may feel tired and lacking in the energy you need for your planned training session. But the likelihood is that you are emotionally and mentally rather than physically tired, so a quick mental and emotional break – *eg* walking the dog, playing with the kids or doing some housework – before training is what you need. Without this break, your mind may not be on the job during training and your performance will suffer in consequence. Conversely, a low intensity, low skill training session is often seen as a great stress reliever for a lot of athletes after a hard day at work.

'If you get caught in the negative loop of self-doubt and self blame, recovery cannot begin'

Self-awareness is an attribute that allows you to recognise how you are feeling physically and mentally and how that affects your reactions to others. Are you getting irate with other people over apparently trivial matters? Is your neck stiff? Do you have trouble concentrating on simple tasks? By identifying your current relaxation status you can determine and implement the appropriate recovery strategy.

Cognitive recovery

A period of adjustment is needed between the experience of a stressful situation and the start of emotional or mental recovery. How many of us can simply 'switch off' after a hard day at work? Everyone has some sort of coping mechanism that allows relaxation to occur, but unfortunately the popular coping mechanism of sinking a couple of pints or glasses of wine may not prove an aid to effective training! This period of adjustment has been described as 'deactivation', and it is necessary to prevent the stressor from one situation (such as work, coach, family) impacting on another situation (*eg* competition, family dinner, school exams) [6].

Table 2: the cognitive recovery process

1. Deactivate – list what went wrong, and why, as well as what went right
2. Plan how to change the things that went wrong
3. Review all the things that went right and throw away the list of things that went wrong
4. Start another activity of your choice – *eg* social activity, low level physical activity, reading, listening to music, movies *etc*, relaxation tape or script
5. Sleep

Sample relaxation script

Let your mind wander to the scene of a beautiful country garden. Look how it is laid out – the lawns, the trees and the flowers. It is a summer's day, just after a light rain shower. Smell the fresh air, feel the damp and moist atmosphere on your skin. Can you smell the flowers, imagine the scent of lavender, or honeysuckle? The grass has just been cut – can you smell it? Now walk down the path into the shade of the trees, look at the texture of their bark and feel how cool it is. Now walk back into the sunlight, feel its warmth on your face, see the butterflies on the shrubs and hear the distant sound of a lawnmower…

Similar scripts can be found in most self-help sport psychology books, but it is best to write your own script based on a very relaxing environment that you have experienced personally. You can then record this onto a tape or CD and listen to it when travelling.

Sleep, for example, is an aid to mental as well as physical recovery. But without an intervening period of deactivation, sleep can be disturbed, leading to further mental and physical fatigue.

How then can we deactivate? The first point to make is that it takes time and has to be an active, positive process [7]. Simply trying to switch your thoughts away from the stressor without addressing it will simply defer rather than banish those thoughts.

How do you react after a bad performance or training session? Do you analyse what went wrong and what you can do next time to put things right? Or do you concentrate on the consequences of what went wrong and blame yourself for your lack of ability? Guess which method allows you to deactivate? If you get caught in the negative loop of self-doubt and self-blame, recovery cannot begin.

Deactivation is particularly important when you are at a training camp or in a situation that involves travelling home with the rest of the team. Often there will be a team meal and a rush from warm-down to shower to give people time to eat before getting on the coach. The physical recovery is taken care of to a certain extent, but an individual deactivation and **cognitive** recovery strategy is still necessary *(see table 2, below left)*.

Having relaxing music or a relaxation script on hand (*see example above*) can help to create a sense of personal space, which allows for deactivation without isolating you from your team mates. Using a script takes practice, however, and you need to get used to relaxing on your own in a quiet familiar environment, such as your bedroom, before you try to do it in more stimulating and stressful situations.

Physical recovery

Physical recovery should start as soon as the session ends, with warm-down, refuelling and showering taking priority. The other methods in the toolbox, listed in table 3, opposite, can be used as desired before the start of the next training session. Note, though, that while sleep is listed as a physical recovery strategy, it is not strictly necessary for physical recovery. The absence of movement is sufficient to allow the body to heal physically; sleep is more essential for mental and emotional recovery. An athlete who is tired from lack of sleep can still train physically; it is just that the motivation to train is reduced by sleep loss!

‘If social functioning is going well, an athlete is better equipped to deal with the physical and mental stress of sporting life’

Emotional recovery

Some stressful situations are primarily emotional, but the inability to cope with these stressors can lead to a greater perception of stress and a consequent reduction in physical health and performance [8]. The stressors that affect athletes in this way can arise either outside the sporting environment – *eg* relationship problems – or within it – *eg* selection issues. Wrisberg and Johnson have defined these respectively as primary and secondary social functioning [9]. If social functioning is going well, an athlete is better equipped to deal with the physical and mental stress of sporting life. If it isn’t, the ability to cope with stress is inhibited, leading to inadequate recovery and consequent performance decline.

Let’s consider the hypothetical example of two university football players who go home for a much-needed Christmas break after playing twice a week for the last 13 weeks. Both have to prepare for exams in January, which they have to pass to stay on at university.

Table 3: physical recovery strategies

- Light aerobic activity – less than 50% of $V0^2max$
- Stretching
- Massage
- Contrast showers – alternating 30 secs hot with 30 secs cold for 4 minutes
- Sleeping or lying down still
- Cold/ice baths – up to 5 mins
- Food
- Hydration
- Whirlpool baths

The first player is looking forward to the break because he enjoys Christmas with his family and catching up with old friends. He enjoys his time at home and is able to study for his exams.

The second player dreads Christmas because his parents are divorced and he has to try to balance time with both of them, as well as working to pay off some debt. He ends up driving for most of Christmas Eve and Boxing Day and is too tired after work to revise. When soccer training resumes in January, the first player is refreshed and looking forward to training, the second player is tired and can't concentrate during training because of exam worries.

The primary social functioning, involving close family members and friends, is a support system. This support can be expressed in emotional, financial or practical terms.

Think of a young tennis player who is trying to make her way up the junior county rankings. She has to play lots of matches to gain points and will win some and lose some. Her parents have to provide emotional support when she loses a match, financial support by paying for the entry fees, equipment and coaching, and practical support by making sandwiches, driving to the venue, washing kit *etc*.

At the opposite end of the spectrum, at a very high level of sport, some athletes have an entourage to help with practical

Table 4: emotional recovery strategies

- Spend quality time with close friends and family
- Make sure you have a support network in place to provide financial, emotional and practical help
- Spend time away from the sporting environment – *eg* pursuing another hobby
- Spend some time with team mates outside the sporting environment
- Spend some time on your own for reflection

matters (*eg* the touring party of the British and Irish Lions) and may also be paid. Nevertheless, they will still need the emotional support.

Secondary social functioning is about the athlete's ability to deal with team mates, coaches and the media. This comes down to individual preferences, with some athletes liking a social atmosphere and others needing some personal time. If an athlete experiences conflict in this area, his ability to recover will again be hampered.

'To allow for balance and full emotional recovery, time must be spent on enjoyable activities outside the sporting arena'

The demands on an athlete's time are huge at most levels. These demands are both internal (striving for perfection, the desire to succeed) and external (*eg* exams, expectations of coach and team mates). To allow for balance and full emotional recovery, time must be spent on enjoyable activities outside the sporting arena. This needn't – and probably shouldn't – involve staying out all night drinking with your non-athlete friends. Instead, activities like going out to dinner, watching a movie, going for a walk or listening to music will all allow you to relax and recover emotionally without having a detrimental effect on your health and performance.

In summary...

This article has identified some recovery strategies that may help athletes deal with physical, emotional and mental stress and so reduce overtraining risks. The important thing to remember is that, as with physical training, an effective recovery strategy must be customised to an individual. While certain requirements are common to all athletes and can be offered in a team situation – *eg* food, water and physical rest – most recovery activities are a matter of personal preference and depend on individual circumstances, including home and work life.

Athletes should be aware of what works best for them, and also of their current recovery status – *ie* whether they need a complete break or just a bit of time to do something enjoyable. Coaches, for their part, should give the members of their teams some discretionary time every day to allow for individual recovery needs to be expressed.

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Overreaching – do it right or pay the price!

At a glance

- The concepts of overtraining, functional overreaching and non-functional overreaching are explained in the context of a training programme;
- Advice is given on how to measure and plan for functional overreaching, without overtraining;
- Simple tests linking performance and overreaching are outlined.

Pushing the boundaries in training is essential for any athlete seeking maximum performance. But as James Marshall explains, if you want to avoid overtraining, there's a right way and a wrong way to do it.

As previously mentioned in the previous article, it is relatively easy to monitor training loads in the gym, the pool, the track and so on. However, it's much harder to monitor the training stress accumulated through matches, races and team training sessions. It's even harder (if not impossible) to monitor stresses incurred outside the training environment or poor lifestyle behaviour, such as exams, financial worries, moving house, relationship difficulties, nutritional and sleep behaviours and so on(1).

As a coach it is critically important to recognise when an athlete is likely to suffer from **overtraining syndrome** (OTS) and more importantly how to prevent it. However, this is made difficult by the fact that markers for OTS are very similar to those for 'overreaching'. Similarities are also found in symptoms of chronic fatigue syndrome and depression, which

Jargonbuster

Overtraining syndrome (OTS)
When an athlete has prolonged maladaptation to training or outside factors. Needs to be diagnosed and treated with rest, usually for more than two weeks

Jargonbuster

Functional overreaching
The planned workload of an athlete that causes a short-term performance decline, but will result in performance increases with rest

Non-functional overreaching
The workload of an athlete that causes more short-term performance decline than planned

makes the diagnosis of OTS difficult[2].

A recent review of literature for the overtraining syndrome by Romain Meeusen and others gave a list of potential causes for OTS and how to identify them[3] (*see box 1*). The authors also defined the terms **functional and non-functional overreaching**. Functional overreaching is a necessary part of training, especially during training camps or perhaps the off season, when there is no need for immediate performance improvement. Here the conditioning coach will deliberately schedule sessions in a sequence that does not allow full recovery. In the short term this leads to performance decrements, but following a period of rest, the athlete recovers and performs better.

Non-functional overreaching

Non-functional overreaching is when an athlete becomes tired or underperforms due to an unplanned overload in training or match scheduling; or if the planned overreaching does not result in performance improvement after a short rest.

An example of this was found in college American football players during their pre-season training[4]. The pre-season was split into three phases:

A magic marker?

Identifying a marker that distinguishes between an acute physical or psychological response to exercise and a chronic maladaptation to the training is not yet possible. A true indicator of overtraining would be a marker that identifies the exact time that the athlete moved from an overreached state to an overtrained one. Instead, studies have identified psychological, immune, hormonal, biochemical and performance tests that are found in these overreached athletes[3] .

If an athlete presents to a doctor with symptoms, it could also be due to other factors such as poor dietary intake, or the response to an infection. The doctor has to rule out allergies and nutritional deficiencies such as iron before diagnosing overtraining. Meeusen et al have suggested a checklist that doctors go through to establish whether true overtraining is present (*see box 1 above right*). It is important that the doctor you see is familiar with overtraining and does not just diagnose a different illness with similar symptoms.

Box 1: Diagnosis of OTS checklist

- Fatigue – sleep disorders, persistent fatigue, unexplained underperformance, increased sense of effort in training.
- Other diseases, including – anaemia, Espstein Barr virus, Lyme disease, eating disorders, muscle damage (increased creatine kinase present), adult-onset asthma, other allergies, and endocrinological diseases such as diabetes or thyroid problems.
- Planning errors identified as leading to overtraining include:
  - Training volume increased by more than 5% /week, measured by hours or km/week;
  - Training intensity increased significantly;
  - Training monotony present;
  - High number of competitions;
  - In endurance athletes – decreased performance at anaerobic threshold;
- Exposure to environmental stressors such as altitude, heat and cold;
- Other psychological signs and symptoms; social factors (family, friends, financial, work, team, coach); recent or multiple time zone travel;
- Exercise tests compared to baseline measures; maximal test results; sub-maximal or sports specific test results; multiple performance tests.

(Meeusen at al, 2006[3])

- Phase 1 was four weeks of weight training;
- Phase 2 was weight training with coach-led conditioning drills;
- Phase 3 was football-specific practice drills.

The second phase of training had a high volume of drills, working on aspects of agility, speed and tackling. The plan was that this period of conditioning would lead to performance improvements ready for the football-specific phase 3. However, what actually happened was that strength and power decreased during phase 2, after increasing in phase 1, and did not return to baseline values until after phase 3.

The authors concluded that the drills conducted in phase 2 were too high in volume, not allowing adequate time for adaptation. The drills included speed work and agility work, but involved continuous effort, so were actually helping the athletes deal with lactic acid build up. However, due to the high rest:work ratios in matches, this is not a key element in American football. Therefore, this programme resulted in non-functional overreaching, leading to performance decrements, rather than increments.

Measuring overreaching

If functional overreaching is a necessary part of training, how can you distinguish between an athlete who is overreached and one who is overtrained? Unfortunately, this is not yet possible to do by looking at just one indicator(3). One of the reasons for this is that due to the ethics involved in studying overtrained athletes it is a difficult area to research; by definition, studies have to be retrospective as no ethics committee, or indeed athlete, would allow actual overtraining to take place, which may then take months to overcome and result in severe performance decrements. Studies that have looked at this area have generally induced an excessive overload of exercise on the athlete over a matter of weeks, but this is overreaching, not overtraining.

‘How can you distinguish between an athlete who is overreached and one who is overtrained?’

Overtraining is a syndrome that lasts weeks or more usually, months(5). It is more common in experienced athletes, who have a greater training history. Their training volumes and intensities are generally higher than in novice athletes. Novice athletes do not have to have to undergo such high levels of volume and intensity simply because nearly all stimuli have a training effect. Experienced athletes on the other hand are better able to perform at higher workloads and deal with fatigue.

Moreover, novice athletes may not have the experience, desire or physical capacity to work hard enough to provide long-lasting fatigue. The individual session will cause enough fatigue to warrant rest, they are unlikely to do two or three sessions in the same day, and then try again the next. Conversely, elite athletes do know their own bodies better and can identify the difference between just being tired or actually being in danger of overtraining. However, in a group environment, where selection for the team or squad is very important, then the pressure to train harder and more often can lead to OTS – that's why coaches need to be involved.

Planning

There is a need to balance stress and recovery (physical, emotional and mental) in any athlete's life[6]. While most strength and conditioning coaches and individual sports coaches will periodise their training programmes, coaches in team sports who run group sessions will often find it more difficult. Here, monitoring the state of athletes during the season is essential to help identify potential problems.

However, some things can be put in place. The use of 'hard', 'very hard' and 'easy' sessions can be planned into the week. For example, an agility session that works on movement patterns could be termed 'easy' and done on a recovery day. But, if the coach then reduces the recovery time, increases the volume of the drills and encourages the players to move faster all the time, then this session quickly becomes 'hard'. Done on the day after a match, this hinders recovery and the athletes would then go into their planned 'hard' sessions even more fatigued. How many times have you seen a coach 'adapt' a training session because they didn't think the players were working hard enough?

'Elite athletes know their own bodies better and can identify the difference between just being tired or actually being in danger of overtraining'

Proper planning is also essential to prevent monotony of training and too much volume, both precursors to overtraining. It is equally bad to have players on their feet for six hours a day doing mindless repetitions at sub-maximal pace as it is to have them work at maximal intensity for prolonged periods. Sets, reps, load, speed, time and distance in the gym or on the track can all be planned quite easily, and volume and intensity can be manipulated according to what stage of training the athlete is in.

For example, in pre-season training in semi-professional rugby league players, a six-week progressive overload followed by a seven-day taper was found to improve performance[7]. Measuring power, endurance and strength, the researchers found that the rugby players' functional performance was

Example of outside influences on performance

As a coach, suppose you have two athletes (A and B), and you plan to do three track sessions with them this week, then give them the weekend off and increase the intensity next week. This is part of a three-week step periodised programme, where you will have an easier fourth week to unload and allow more adaptation. At the beginning of the fifth week you do a time trial and athlete A has improved their time. Athlete B has not. Your immediate reaction may be to increase the workload on athlete B. But what else has happened?

It may be that athlete A goes home after training, eats well, does his homework, and spends some time with his friends and goes to sleep. Athlete B, however, may be returning home to find his parents arguing. He walks out of the house and goes to get some fish and chips. He comes back home and can't sleep properly due to anxiety. Three weeks later his Mum moves out and he does too. He falls behind in his school work, and is in trouble with his teachers. His physical recovery has been affected through disruption; his emotional recovery is nonexistent due to the family break up. This means his body has not been able to adapt to the training programme. If the coach knows his athlete well, he will realise and understand about the outside influences and adjust the training load accordingly.

adversely affected by the six weeks of training. The players had increased both their training volume (six hours per week to 13 hours per week) and intensity over the six weeks. Their training included weights, endurance training and rugby sessions. In the seventh week, training volume (5.5 hours) and intensity were both reduced, to allow adaptation to take place. After the taper, the players were again tested and their strength, power and endurance scores had improved. This is an example of functional overreaching. The training programme was designed to overreach the players, rest them to allow adaptation, and then start training them again.

Of course, this study only provides one example of functional overreaching; a longer or shorter taper, with lesser or greater amounts of work may be more suitable in different circumstances. With team sports, however, the imminent season and the coach and athletes' desire to keep their jobs by winning often curtail the luxury of experimentation.

Performance indicators

While planning is essential, monitoring the effectiveness of your plan is even more important. The use of detailed training diaries can help identify performance decrements in their early stages, or before they actually happen. If an athlete identifies fatigue for seven consecutive days or more, then the coach needs to address this with a reduced training load, and then look at what factors may be causing this fatigue. This monitoring of diaries is easy enough in individual sports but within team sports some form of online monitoring and recording may be necessary. Software that shows changes in profile at a glance allows coaches to monitor a squad of 30-40 players more easily.

The use of questionnaires such as the 'REST-Q' and the 'Daily Analyses of Life Demands for Athletes' (DALDA) have been shown to be effective in indicating overreaching(9,10). However, this can become an exercise in futility if both the coach and athlete are not already 'sold' on the idea; both parties need to be educated on the effectiveness and purpose of the monitoring.

Junkyard training

Other methods of training that combine strength and endurance are more difficult to measure. One example is so called 'junkyard' or 'strongman' training, popular in physical team sports. Junkyard training involves lifting heavy, cumbersome implements using non-traditional movement patterns. These sessions can place huge metabolic demands on athletes, which may not be factored into the overall training plan. If the demand cannot be measured, then how can the proper rest be taken and subsequent sessions planned? If they are seen as a bit of fun, then non-functional overreaching could take place. If adequate rest is given, and some progression put into the sessions, then the fatigue would be functional overreaching.

A study on the amount of energy required to push and pull 1,960kg trucks highlights the demands of junkyard training (8). Six male athletes were required to either push or pull the vehicle for 400m as fast as possible. Blood lactate levels averaged 15.6mmol/L, which was 131% of the value of their maximal running test on a treadmill! No wonder all the subjects reported feeling dizzy and sick afterwards. This is an extremely demanding activity, and while activities like this are fun and relevant for a lot of sporting activities, the corresponding recovery needs to be in place.

More importantly, an agreement has to be in place about resting players if signs of non-functional overreaching are present.

Physical tests may be easier to administer and can be effective. The problem is that you need a baseline score, and sub-maximal tests do not appear to be as effective[11]. Other factors such as sleep quality, daily variability and adaptation to training can alter heart rate responses to sub-maximal exercise. The multi-stage fitness test has been found to be an indicator of non-functional overreaching, but the practicalities of submitting a team of athletes to this week in, week out to see if they are fatigued may be hard to justify[9].

‘For sports where most training is spent ‘on feet’, the five-bound test could be an effective, quick and cheap method of measuring current performance, without overstressing the athlete’

A simple test that was used in a study on triathletes is the ‘five-bound test’ (5BT)[11]. This test starts with the athlete on their preferred foot. He or she then bounds for distance on alternate legs five times and the distance from the start line to the rearmost point of the heel on the fifth bound is measured. In a study, triathletes were split into two groups that completed four weeks of training, followed by a two-week taper. The first group followed an intensive training (IT) protocol that resulted in a deliberate overreaching. The second group followed a self-selecting normal training (NT) protocol that increased in volume over the four weeks. The IT group experienced a training load 290% greater than the NT group over the four-week training period.

While the NT group did not experience any significant performance changes over the six weeks, the IT group did suffer. Their 5BT scores reduced from an average of 11.4m at the beginning of training to 10.5m at the end of the four weeks of training. After the two-week taper, this increased to 11.5m. For sports where most training is spent ‘on feet’, the five-bound test could be an effective, quick and cheap method of measuring current performance, without overstressing the athlete.

Summary

Training without adequate recovery can lead to reduced performance, illness and interrupted training. Coaches must therefore get to know their athletes well and monitor how they are feeling. If short-term performance decrements are only 'rewarded' with more work, then a gradual decline will occur which could lead to the overtraining syndrome, and the loss of the athlete to the squad for months. Planning each week and month will help prevent the loss of training sessions, but having the flexibility to adapt to each individual's needs will result in more athletes progressing and being available for selection. A five-minute conversation with every athlete each week could save hours of trouble later in the season!

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Optimum nutrition for athletes – what can we learn from recent studies?

At a glance:

- Evidence is presented that some athletes may be neglecting dietary basics;
- Athletes who seek nutritional assessments to improve basic diet are offered guidance on how to select a nutritionist;
- The most common nutrient deficiencies and strategies to avoid them are presented, together with food recommendations to avoid them.

Ask sportsmen and women what they think are the key issues in sports nutrition and the importance of optimising carbohydrate intake, using protein to aid lean tissue growth, or specific ergogenic aids like creatine will probably feature in their responses. But, according to Andrew Hamilton, there's evidence that many athletes may be neglecting the dietary basics, something that can significantly reduce recovery and increase the risk of overtraining.

Punch 'sports nutrition' into any internet search engine and you'll get a deluge of results from sports supplement companies and retailers, all offering products claiming to enhance sport performance. Likewise, the shelves of most sports and health food retailers are crammed to overflowing with 'sports nutrition' products – an Aladdin's cave of pills, powders and potions!

But while there *have* been great technological advances in sports nutrition products, these types of products do not

Jargonbuster

Ergogenic
A substance that enhances sports performance either directly, or indirectly via improved response to training

RNI
Reference Nutrient Intake; the daily amount of a nutrient required to produce health (*NB.* many countries still use the term RDA, or Recommended Daily Amount)

automatically guarantee optimum nutrition for athletes in hard training. Indeed, a reliance on products such as carbohydrate and protein powders, fluid replacement drinks and **ergogenic** aids may help to foster a 'performance from a bottle' mentality – an assumption that today's high-tech sports nutrition formulations can guarantee optimum performance.

However, this assumption is flawed. Relying heavily on sports nutrition products may actually lead to a *poorer* basic diet quality, because many athletes simply assume that they no longer need to worry about eating high quality natural foods, leading to a reduced intake of key nutrients. A poorer, low-nutrient diet is undesirable for a number of reasons, but particularly because such diets are associated with lowered immunity and a generally reduced resilience of the body to withstand the day-in, day-out rigours and cumulative stresses of training , which in turn can increase the risk of overtraining.

Supplementation is no universal panacea either. Even the most advanced nutrient supplement in the world will contain only a minute fraction of the vast number of naturally occurring beneficial substances that are continually being discovered in food – substances that may help to keep athletes healthier, thereby minimising time lost through illness and injury.

Athletes often lack nutritional knowledge

It's a generally accepted theory of sports nutrition that athletes don't need to supplement nutrients because their increased energy expenditure means they eat more food to fuel activity. Provided this extra food also contains nutrients, the net result of a higher calorie intake should be a greater overall nutrient intake.

For example, suppose a male sedentary office worker weighing 70kg consumes about 1,800kcals per day and the food that provides those calories supplies around the **RNI** of 1.4mg of vitamin B6. Now suppose he begins a training programme, averaging 10km of running per day. Assuming the energy cost of running is about 1 kilocalorie per kilogram of body mass per kilometre, our newly active office worker will need to consume around 700kcals extra per day (*ie* 2,500kcals in total) to fuel this activity. If he continued to eat exactly the same foods, but simply increased portion sizes to meet this increased energy demand, we would expect a proportional rise in his vitamin B6 intake from 1.4 to 1.95mg per day (25/18 x 1.4mg) – more than enough to meet any increased metabolic need.

However, while this theory is broadly true, there are three implicit assumptions:

1. The basic quality of the diet is nutritionally balanced, supplying sufficient amounts of key nutrients;
2. The 'extra' calories consumed to fuel training are also derived from nutritious foods and not from 'empty calories' (*eg* sugary foods such as confectionary, junk food and fizzy drinks);
3. An athlete has no special needs – *eg* female athletes undertaking high-impact sports such as running and who are now thought to have significantly higher iron requirements.

While these assumptions seem perfectly reasonable, it's surprising how many athletes appear to lack the knowledge required to help them make healthy food choices. For example, a study carried out in the early 1990s evaluated the nutrition knowledge and dietary practices of four groups of women (1):

- 18 postmenopausal women;
- 14 college-aged dancers;
- 13 members of a college track team;
- 14 non-athletic college women.

All the subjects completed a personal information questionnaire, a 24-hour food recall, a food frequency questionnaire and a nutrition knowledge test. Although the track athletes scored significantly higher in the knowledge test than the dancers (26.5 vs 22.2), they scored less well than the postmenopausal women (28.5) and the non-athletic college women (29.7).

A recent study compared the nutrition knowledge and dietary composition of Italian athletes and non-athletes (2); 60 athletic and 59 non-athletic adolescent females completed

'Many athletes are still confused about what constitutes a healthy and nutritious diet required to support training'

3-day food recall and nutrition knowledge questionnaires. Although the athletes reported higher carbohydrate, iron and fibre intakes and consumed lower fat, the intakes of calcium, iron, and zinc were still less than the recommended dietary allowance for these nutrients. Furthermore, while the athletes gave a slightly higher rate of correct answers on the nutrition knowledge questionnaire than non-athletes, the difference was quite small (77.6% vs 71.6%).

Another study examined the dietary practices, attitudes and physiological status of collegiate freshman football players in Atlanta and reported that over half the group believed that protein supplements were necessary for muscle growth and development, and that protein was the primary source of energy for muscle (3).

It's clear from these and other studies that while the age, type of sport and cultural/social background of athletes plays an important role in determining the quality of diet, many athletes are still confused about what constitutes a healthy and nutritious diet required to support training. There's also evidence that even when athletes are more knowledgeable about and have more positive attitudes towards, nutrition, they still fail to follow it up with improved dietary practice (4).

Evidence for sub-optimum nutrition in athletes

Do the poor nutritional knowledge and practices observed in some studies translate into sub-optimum dietary intakes in practising athletes? This is a complicated issue and the answer depends very much on which studies and which groups of athletes you look at (*see box, above*).

As you might expect, many studies on elite athletes (who often have access to specialist dietary advice and even a dedicated dietician) have not demonstrated wholesale dietary deficiencies. For example, a US study carried out on 19 elite female heptathletes (average age 26 years) combined data on body composition, dietary nutrient intake, dietary practices and biochemical indices of iron status during training (5). Apart from vitamin E, average nutrient intakes were over 67% of the

Challenges of assessing nutritional status

Assessing nutritional status accurately and drawing firm conclusions is no easy task. For example, studies that rely on athletes 'self-reporting' their dietary intake are beset with potential problems; it's a well-known phenomenon that what we eat and what we *think* we eat may not be quite the same! There may also be occasions where an athlete deliberately over-or underreports the intake of a particular food or food group, for example to keep the coach happy, or perhaps as a result of an eating disorder.

These difficulties can be minimised if any assessment is also supplemented by biochemical testing for nutrient status; *ie* as well as examining dietary patterns to see whether there are likely to be nutrient shortfalls, you then measure nutrient levels in your subjects to see if these are actually borne out in practice. If a nutrient shortfall is detected by both criteria, you can be pretty sure that an athlete really is short of that nutrient. However, studies that also include biochemical testing (as opposed to simply dietary screening) are time-consuming and expensive, and are therefore less numerous in the scientific literature than simple dietary screening studies.

Another complicating factor is the fact that many studies assess groups of athletes who train together, *eg* from a squad, team or club. These athletes will almost certainly be comparing notes, swapping experiences and taking advice not only from the coach, but also from each other. This inevitably means that there'll be some degree of sharing of nutritional approaches and practices, which in turn means that the results of any study carried out on a group may be only particularly relevant to that group and not more generally. For example, a study on a group of swimmers drawn from a squad may reveal a dietary shortfall of calcium, but it could be that a couple of the stronger personalities in that squad had persuaded the other squad members that avoiding dairy produce (a rich source of calcium) would help performance. Given this scenario, it would obviously be a nonsense to draw the conclusion that swimmers generally are at risk of a calcium deficiency.

recommended intake and most **nutrient densities** were higher than the recommended densities for women in this age group. However, there are plenty of other studies suggesting that athletes from a wide range of sporting disciplines and levels may be at risk from sub-optimum nutrient intakes as a result of either a poor understanding or inadequate execution of the basic dietary principles.

For example, a study examined the nutritional status of eight Brazilian male elite swimmers by means of a 4-day food record, a fasting blood sample and body composition measurements[6]. Although the dietary assessment showed a generally adequate

Jargonbuster

Nutrient density
The nutrient content of a food per calorie consumed; nutrient dense foods contain high levels of nutrients for each calorie of energy they provide

Common dietary pitfalls

Although different dietary patterns produce a huge amount of inter-individual variability in nutritional status, a few common pitfalls are frequently observed. The table below shows some of the most common nutrient deficiencies observed in athletes, their possible causes and good food sources that can help improve the status of that nutrient.

Nutrient	Important function(s) for athletes	Causes of/risk factors for shortfall	Good food sources
Calcium	Bone growth/ maintenance; muscular contraction; nervous system and hormonal signalling	Calorie restriction (dieting); diets low in dairy produce (the richest source of calcium)	Milk, cheese, yoghurt, tinned fish (with bones), green leafy vegetables, nuts and seeds
Iron	Haemoglobin production for oxygen-carrying red cells; enzymes involved in energy metabolism; immunity	Low-meat or vegetarian/vegan diets; large intakes of tea with meals (which contains iron-blocking tannins); pounding sports such as distance running; monthly blood losses in pre-menopausal women	All red meats such as beef, liver, kidney; shellfish, sardines, eggs, prunes, sunflower seeds
Zinc	Protein turnover and muscle growth; immunity; metabolism during 'stress'	Low-protein diets; stress; excessive alcohol consumption; refined/junk diets grain/wholemeal	Beef, eggs, herrings, pork, oysters, almonds, brazil nuts, pumpkin seeds, walnuts, whole-breads and cereals
Magnesium	Energy production via ATP; carbohydrate metabolism; nervous system and muscular function	Refined diets or those low in wholegrain cereals, green vegetables, pulses and nuts and seeds; excessive alcohol consumption;	Almonds, brazil nuts, dark green vegetables, buckwheat flour, peanuts, chickpeas, sesame seeds, beans and lentils, wholegrain cereals
Vitamin C	Immune function; connective tissue (ligaments, tendons) integrity; aid to iron absorption; long-term protective effect (protection against oxidative stress)	Low fruit and vegetable intake; stressors such as illness, injury, or psychological stress	Blackberries, broccoli, Brussels sprouts, kiwi fruit, cabbage, limes, lemons, peppers, new potatoes, oranges, grapefruits, tomatoes, strawberries, watercress
Essential fats	Hormonal synthesis; energy regulation (via insulin); possible role in fat metabolism and weight control	Low-fat diets, high saturated or processed fat diets, excessive alcohol intake; contraceptive pill	Fatty fish (trout, salmon, sardines, mackerel, pilchards, herrings), some nuts (eg walnuts), sunflower and pumpkin seeds, wheatgerm and wholegrains, some margarines
Folic acid	Regulation of the formation of red blood cells; helps iron to function properly in the body; cell growth and turnover	Low-calorie diets, or diets rich in fast/junk food; low vegetable intake; regular use of antibiotics or anti-inflammatory medication	Spinach, dark leafy greens, asparagus, turnip, Brussels sprouts, beans, liver, brewer's yeast, root vegetables, wholegrain breads and cereals, wheatgerm, oysters, salmon, orange juice, avocado and milk

intake of calories, vitamins and minerals, only half the group were consuming the recommended daily intake of calcium. Moreover, carbohydrate intakes were insufficient, resulting in high levels of an **enzyme** called creatine-kinase – a sure sign of increased muscle degradation.

More evidence is available from other studies. A study of female judo athletes examined the nutritional status, iron-deficiency-related indices and immunity of female athletes [7]. The subjects' 3-day food records were evaluated for a range of nutrient intakes and compared to a group of controls. Although intakes of energy, protein, phosphate, vitamin B1 and niacin were higher in the judo athletes than the controls, intakes of the minerals iron and calcium still failed to meet the recommended daily allowance. In addition, levels of immunoglobulin (Ig)G (a blood protein that can be used as a marker of immunity – higher levels indicate better immunity) indicated slight immunosuppression in the athletes – those with the lowest dietary intakes of iron, B1 and niacin exhibiting the lowest (Ig)G levels.

Meanwhile, a Spanish study looked at the magnesium, zinc and copper status of 78 women involved in karate, handball, basketball and running[8]. A 7-day food intake was gathered with all subjects weighing food portions to improve the accuracy of the data and the results compared with those of a control group of 65 sedentary women. The results were not encouraging; although better than the controls, no group of female athletes reached the then recommended daily intake for magnesium (280mg) or zinc (12mg), intakes that have since been revised upwards. Moreover, the handball athletes also failed to meet their daily needs for copper.

A US study on elite figure skaters used 3-day food records to look at the energy and **macronutrient** intakes of 80 males and 81 females taking part in a series of training camps held in Colorado between 1988 and 1995 [9]. Of particular interest was what proportion of their carbohydrate intake was consumed as complex, unrefined (nutrient-rich) carbohydrate, and what proportion as refined simple carbohydrate (*ie* sugars). Worryingly, the skaters derived in excess of 25% of their daily

Jargonbuster

Enzymes
Large protein molecules synthesised by the body to speed up biochemical reactions that would otherwise occur extremely slowly or not at all

Macronutrients
Nutrients needed in comparatively large amounts by the body (*ie* protein, fat, carbohydrate, fibre and water)

energy intake from sugars (typically around 100-142g of sugars per day). The current consensus among nutritionists and health promotion agencies is that no more than 10% of calorie intake should come from refined sugars, not least because these sources of carbohydrate tend to be very low in vital nutrients.

Another study in the late 1980s at the University of Alabama studied eight highly trained female cyclists and also found their diets wanting [(10)]. Each cyclist kept a 3-day weighed food record and diets were analysed for nutrient content, while blood tests were also carried out. The results were far from ideal; not only were the cyclists' diets low in carbohydrate, mean daily dietary intakes were also well below the RNIs for folic acid (76% RNI), magnesium (81% RNI), iron (59% RNI), and zinc (48% RNI). In addition, more than one-third of the cyclists failed to consume even two thirds of the RNI for vitamins B6, B12, E and the minerals magnesium, iron, and zinc. The researchers noted that foods such as meats, poultry, fish, beans, peas and nuts were low or virtually absent from many of these cyclists' diets.

These findings are pretty dismal, but surely the explosion in nutrition research and education over the past 15 years would make it unlikely that 21st century athletes could commit such basic nutritional sins? Unfortunately the evidence suggests otherwise. A 2002 US study on 23 nationally ranked female volleyballers provides more evidence that some athletes may still be struggling to fulfil even basic nutritional needs [(11)]. Nutrient and energy intakes and energy expenditure were determined by 3-day weighed food records and activity logs, while blood tests were taken to measure nutrient status. Mean intakes for folic acid, iron, calcium, magnesium and zinc were all less than the respective RNIs for these nutrients, while 50% of the athletes were consuming less than the RNIs for the B-complex vitamins and vitamin C. To make matters worse, both carbohydrate and protein intakes were found to be inadequate for athletes of this activity level, while three athletes presented with gross iron deficiency anaemia (blood haemoglobin less than 12mg/dL) and a marginal vitamin B12 and C status were found in one and four athletes, respectively.

Avoiding the pitfalls

It's clear from these and other studies that while many athletes may be more knowledgeable about nutritional basics than their sedentary counterparts, and more motivated to translate this knowledge into action, some are still unwittingly neglecting the dietary fundamentals, increasing the risk of poor recovery and overtraining syndrome. This being the case, you might at this point be wondering whether your own diet is up to scratch, or whether there are certain areas that could be improved.

As we've already hinted, building a detailed and accurate picture of nutritional status is a time-consuming process, which needs to be carried out by a suitably qualified professional. If you suspect that your diet falls short of your nutritional requirements and wish to have a proper assessment, you need to ensure that you consult someone who is appropriately skilled and qualified to carry out what is a potentially complex task. In the UK for example, this means someone who is on the British Association for Nutritional Therapy (BANT) register. A degree background in biological/ biochemical/chemical sciences or nutrition/sports nutrition is also desirable.

'If you wish to have a proper nutrition assessment, you need to ensure that you consult someone who is appropriately skilled and qualified to carry out what is a potentially complex task'

A proper nutritional assessment should consist of at least two elements:

- A detailed food diary containing details of all foods/portion sizes consumed for at least three days and preferably longer;
- A questionnaire about general dietary habits.

In a more comprehensive assessment, this information is often supplemented by one or more biochemical tests carried out on blood, urine and maybe even sweat, but of course these add to the costs. Beware of 'consultants' who claim to offer wacky methods of analysis; hair tests for mineral status are of very limited value, while assessments based on blood groups, pendulums, crystal healing etc are no better than guesswork.

However, you don't necessarily need a full nutritional assessment in order to increase the basic quality of your diet. So long as you remember that a) dietary basics *are* important and

b) that the majority of your diet should be comprised of whole and unprocessed foods such as wholegrain breads and cereals, fresh fruits and vegetables, high quality proteins such as lean meats, fish and low-fat dairy produce, beans and lentils, and nuts and seeds, you'll be on the right track.

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Want to know the key to training success? Plenty of R&R

At a glance:

- The importance of recovery for athletes is explained;
- A heirarchy of recovery strategies to minimise overtraining risk is presented and explained in detail

All work and no rest makes for an overtrained, injury-prone and weakened athlete. Read top conditioning coach Nick Grantham's rules for recovery and reap the benefits.

Talent alone is no longer enough to guarantee victory in the sporting arena. Athletes striving for high level success must push their bodies and minds to the limit [1]. If you cannot adapt to and cope with the physical and mental demands of training, you will quickly become exhausted. So how can we reach the limits of human performance without tipping over the edge? The key lies in one of the simplest yet most neglected training principles: recovery. In the words of one who should know, the seven-times Tour de France champion Lance Armstrong: 'Recovery… that's the name of the game… Whoever recovers the fastest does the best.'

There is very little rigorous scientific research to help us decide which recovery strategies work – we still rely heavily on the accumulated experience of athletes and coaches. Even so, it is possible to set some ground rules and parameters that will enable athletes to tread the fine line between maximising performance and sustaining injury.

Principles of progressive overload

- Training is designed progressively to overload body systems and fuel stores;
- If the training stress is insufficient to overload the body's capabilities, no adaptations will occur;
- If the workload is too great (progressed too quickly, performed too often without adequate rest), then fatigue follows and subsequent performance will be reduced;
- Work alone is not enough to produce the best results; you need time to adapt to training stress;
- To encourage adaptation to training, it is important to plan recovery activities that reduce residual fatigue;
- The sooner you recover from fatigue, and the fresher you are when you undertake a training session, the better the chance of improving.

Progressive overload

Athletes love to train. But in order for the body to adapt it must have a period of recovery. This is not a new concept; it is a cornerstone of everything coaches and athletes should be trying to achieve. To understand the significance of recovery, you need to understand the fundamental principles of progressive overload.

Figure 1 (*below*) illustrates the principle of progressive overload. If we introduce a recovery method at the point of fatigue we can expect to reduce the length of time it will take to recover from training (the broken line represents the gain in recovery time and the light red shaded area represents the

Figure 1: Progressive overload

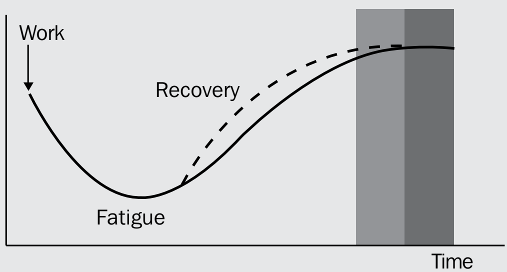
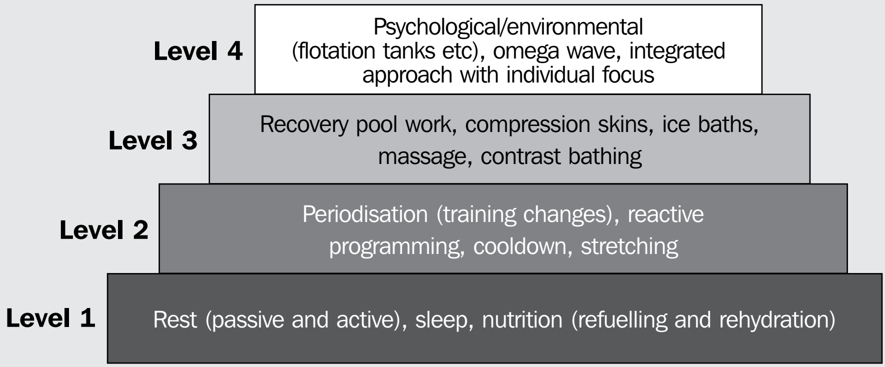


Figure 2: The recovery pyramid



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increased window of opportunity to move on to the next training effort). So you can move ahead with your programme more rapidly.

One of cycling's best coaches, Peter Keen, explains it thus: 'Nature has given the human body a wonderful engine management system. It actually responds to stress by adapting to cope with it better… the bottom line is the body does not get fitter through exercise; it gets fitter through recovering from exercise.'

Before we can introduce a recovery strategy we need to know which type of fatigue we are dealing with. The type of training effort will determine which of a number of forms of fatigue an athlete will experience (1). Table 1 overleaf summarises the main forms.

Recovery strategies

It's easy to get carried away with all the new 'toys' such as compression clothing, ice baths etc, and forget about the basics such as sleep and nutrition. Figure 2 (*above*) presents an overview of some of the recovery strategies that are available and suggests the order in which coaches and athletes should consider them. This list is not exhaustive.

Table 1: Types of fatigue and how they occur

Type of fatigue	Occurs as a result of…
Metabolic (energy stores)	● high volume training ● repeated workloads ● aerobic/anaerobic conditioning ● multiple training sessions throughout day
Tissue damage	● plyometrics ● eccentric loading ● contact sports
Neurological (peripheral nervous system)	● high intensity work ● resistance training (strength and power development) ● speed work ● skill sessions and introduction of new training techniques
Psychological (central nervous system and emotional fatigue)	● training monotony ● lifestyle issues ● heavy game/competition/training period ● pressure plays (training simulating match conditions) ● new training techniques
Environmental	● hot and cold environments ● travel (local, national, international) ● time differences ● competitions

Source: Adapted from Calder A, 'Revive, survive and prosper' (1)

Strategies at Levels 3 and 4 should not form part of the equation until and unless you already have an established regime at Levels 1 and 2. Put simply, if you are not looking after the basics (sleep, nutrition and training), you are not going to get any additional benefit from more gimmicky recovery tools such as compression skins or contrast bathing.

Level 1 strategies
Sleep/rest (passive and active)

Sleep is one of the most important forms of rest and provides time for the athlete to adapt to the physical and mental demands of training. Other forms of passive rest include reading, listening to music and flotation (*see Level 4 activities*).

Active rest activities include walking, cross-training and stretching [2].

Nutrition (refuelling and rehydration)

The most important components for nutritional recovery are fluid and fuel replacement. You should avoid drinks containing caffeine and drink enough fluid (water, cordials or sports drinks) before, during and after training to replace sweat loss. There is a 45-minute window of opportunity for optimal refuelling after a training session. The ideal recovery nutrition strategy (non-sport-specific) is a meal or liquid supplement containing high glycaemic index carbohydrates and quality proteins in approximately a 4:1 ratio that includes 10-20% of your total daily caloric intake of these two macronutrients [3].

'If you are tired, there is little point in training for the sake of sticking to the schedule'

Level 2 strategies

Periodisation

Periodisation is the cycling of the various training elements (strength, speed, endurance, flexibility etc) and variables (intensity, frequency, volume, load) over a period of time in order to ensure you peak for a particular competition or event. A well planned programme will incorporate not just periodised training but appropriate recovery planning [2].

Reactive programming

Once you have a periodised training plan, accept that there will be times when you need to deviate from it – usually because your need to recover will turn out to be different from what was anticipated. It is crucial that both coach and athlete can react flexibly and appropriately to situations that arise during the training programme. If you are tired, there is little point in training for the sake of sticking to the schedule.

Cooldown and stretch

The cooldown is a group of exercises performed immediately after training to provide a period of adjustment between exercise and rest. Its purpose is to improve muscular relaxation, remove waste products, reduce muscular soreness and bring the cardiovascular system back to rest. Stretching is often combined with the cooldown. It is common for athletes to lack sufficient flexibility to perform their sport's movements with the greatest efficiency, so this period immediately after the main workout, in which the body temperature is still elevated, provides a good opportunity to improve your range of movement and reduce your risk of injuries [1].

Level 3 strategies

Recovery pool work

Angela Calder [1] recommends completing a 20-minute pool-based recovery session the day after a heavy training session or competition. Water is an excellent environment in which to conduct a recovery session, providing buoyancy and resistance properties that allow you to train with minimal impact on the body.

Guidelines [2]

Water temperature	20° to 28°C
Duration	10 to 20 mins
Intensity	Light to moderate
Content	walking (forward/backward), side steps, basic swimming strokes and aqua jogging, stretching (static and dynamic).

Compression skins

This is the latest boom business in terms of recovery, and leading sportswear manufacturers are producing garments with 'compression qualities'. Heavy training can cause muscle damage resulting in soreness, swelling, pain and impaired athletic performance [4]. Scientific research has indicated that external compression can be an effective treatment that minimises swelling, improves the alignment and mobility of scar tissue and improves proprioception (sense of body position in space) in an injured joint after eccentric damage and delayed onset muscle soreness (DOMS) [4].

Ice baths/contrast bathing (hydrotherapies)

Contrast bathing: Alternating hot and cold showers/baths provides an increase in blood flow [2] to the working muscles and speeds the removal of lactic acid [1]. Contrast bathing also stimulates the nervous system and helps to increase arousal, because the brain has to receive and recognise two different types of information (hot and cold).

Guidelines [1,2]

Complete within 30 minutes of training/competition
Begin and end with cold
Repeat the alternations 3 to 4 times

Temperature, cold	10° to 16°C
Temperature, hot	35° to 37°C
Shower, cold	30 to 60 secs
Shower, hot	1 to 2 mins
Bath/spa, cold	30 to 60 secs
Bath/spa, hot	3 to 4 mins

‘Research has shown that treatment with cryotherapy improves muscle function, reduces muscle damage and decreases soreness associated with DOMS’

Cold baths (cryotherapy): Cold baths have primarily been used for their pain-relieving properties [2]. But more recently the thinking is that when you plunge your body into a bath full of icy cold water, the blood vessels constrict and the blood will be drained away from the muscles that have been working (removing lactic acid). Once you get out of the bath the capillaries dilate and ‘new’ blood flows back to the muscles, bringing with it oxygen that will help the functioning of the cells. Research by Sam Erith at Loughborough University, UK, has shown that treatment with cryotherapy improves muscle function, reduces muscle damage and decreases soreness associated with DOMS.

Guidelines [5,6]

Keep body parts moving to prevent a ‘barrier’ of warm water forming around the limbs.

Cold temperature	5° to 15°C
Duration	7 to 10 minutes to cool the muscles (shorter for short-term pain relief).

Table 2: Matching recovery strategies to type of fatigue

Type of fatigue	Recovery strategy
Metabolic (energy stores)	● Sleep, rest (passive and active) ● Nutrition ● Hydrotherapies (contrast bathing) ● Massage ● Recovery pool work ● Compression clothing ● Omega wave
Tissue damage	● Sleep, rest (passive and active) ● Nutrition ● Hydrotherapies (cold baths) ● Massage ● Compression clothing ● Recovery pool work
Neurological (peripheral nervous system)	● Sleep, rest (passive and active) ● Hydrotherapies (cold baths) ● Massage
Psychological (CNS and emotional fatigue)	● Sleep, rest (passive and active) ● Flotation tanks ● Omega wave
Environmental	● Sleep, rest (passive and active) ● Hydrotherapies (contrast bathing, cold baths) ● Recovery pool work

Massage

While research results vary wildly, the reported physiological benefits include:

- increased blood flow, enhanced oxygen and nutrient delivery to fatigued muscles, increased removal of lactic acid;
- warming and stretching of soft tissues, increasing flexibility, removal of microtrauma, knots and adhesions.

Reported psychological benefits include:

- Improved mood state;
- Increased relaxation and feeling less fatigued.

Massage also improves your body awareness of which muscles have been stressed (1). Calder advises athletes to spend 10 minutes at the end of a training day performing some self-massage (particularly legs and shoulders) [1,2,7].

Level 4 strategies

Flotation tanks

These provide an environment with minimal stimulation (reproducing weightlessness and eliminating sound and sight). Reducing the level of stimulation to the brain allows us to focus more effectively on relaxing and becoming emotionally calm[1].

Omega wave

Analyses electrical activity in the heart and slow brain waves to provide an 'inside look' at how your body is functioning. You sit or lie down comfortably. Electrodes are placed on the body and the system collects data on electrical activity in the heart and on brain-wave activity, particularly very slow 'omega' waves. It analyses this and produces a report for the coach or athlete.

The system looks at:

- Heart regulation. Is the heart ready to support high intensity loads, low intensity loads, or is it over-stressed, sluggish, or maladapting to previous training?
- Which energy systems (aerobic, anaerobic) need development, which are ready for work and which are in need of further recovery?
- The functional systems that strive for homeostasis (central nervous system, gas exchange and cardiopulmonary system, detoxification and hormonal systems).

Manufacturers claim that, armed with the relevant information, you can work out whether you have recovered from the previous day's competition or training, which energy systems need work, which energy systems are ready to be worked, and the appropriate heart rates – for that particular day – between which you should be working your various energy systems.

It's not an exact science, but Table 2 will give you a head start on which recovery strategy may be the most appropriate for any given type of fatigue. Remember: get the basics established before you try to get too clever.

Conclusion

Recovery cannot be a one-size-fits-all approach. It is a process that should form the cornerstone of a structured training programme, so that athletes can attain maximal physiological adaptations while reducing the risk of residual fatigue that might result in illness or injury [8].

Coaches and athletes are well advised to think about the fundamental principles relating to training and recovery in order to make an informed decision on which recovery method is the most suitable.

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Sport performance – waking up to the importance of sleep

At a glance:

- The importance of sleep for optimum recovery and metabolic functioning is outlined;
- The complex relationship between nutrition (especially magnesium and protein nutrition) and sleep is explained;
- Suggestions are made on how to improve sleep patterns.

We spend around a third of our lives in bed, yet many of us pay little attention to either the duration or quality of sleep. But as Tim Lawson explains, athletes seeking maximum performance and recovery neglect sleep at their peril.

In our modern caffeine-fuelled, 'sleep when you're dead' society, it's easy to form the impression that sleep is not important. The high use of caffeinated sports drinks and pre-workout pick-up formulas by athletes and sports people suggests that it is not just overworked office workers and late night clubbers who are falling into the trap of believing that sleep is not entirely beneficial or useful.

In fact, surveys and scientific studies suggest that chronic sleep loss due to the combination of voluntary bed time restriction and poor quality of sleep is an endemic condition in modern society [1,2,3]. The trend to push sleep aside to make room for busier lives shows no sign of abating and most people are now carrying some degree of sleep debt.

In a British national sleep survey, 18% of people reported that their sleep was insufficient on the majority of nights, and nearly 60% of people reported insufficient sleep on one or more nights of the previous week [1]. It is not just the amount of time in bed that's important; difficulty getting off to sleep or disturbed, restless sleep can also create a significant sleep debt.

In sportsmen and women, the issue of the sleep deprivation problem is not confined to amateur athletes trying to fit training and competition around busy work schedules. Professional sportsmen and women are also vulnerable.

A high-profile example of sleep disturbance in professional sport occurred in the 2006 Tour of California. Top American cyclist Levi Leipheimer looked set for an important victory, having won the opening prologue time trial and ridden strongly in the mountains. He was upbeat about the possibility of taking the overall lead in the next important trial stage, and was the firm favourite for a home win. However, a poor night's sleep meant he was far from fresh in the time trial and a mediocre performance by his standards put him out of contention for overall victory.

'There is now a considerable body of evidence showing that sleep has a huge role in regulating many physiological functions'

Although scientific studies and health bulletins have been talking about restricted and poor quality sleep as a potential health problem for many years, until recently it was still largely thought that sleep was needed purely for the mind. However, sleep deprivation became an increasing health concern with the rising occurrence of traffic and work-related accidents resulting from poor concentration, or people falling asleep whilst in charge of vehicles or machinery. Sleep deprivation is also thought to have played a large role in many large-scale public disasters such as the 1989 Exxon Valdez oil tanker accident [4].

Mind and body

If sleep was needed purely for the mind, athletes could almost have been forgiven for thinking that it was more important just to 'get the workouts done' no matter how tired they felt. If they felt they had not had sufficient sleep then exercising a little mind over matter, helped perhaps by a few strong coffees, would merely make them stronger.

Effects of sleep debt on sports performance

Physiological

Impaired glucose metabolism and the ability to replenish carbohydrate
Reduced cardiovascular performance
Impaired motor function and reaction times
Increased appetite and associated weight gain
Delayed visual reaction time
Delayed auditory reaction time

Psychological

Increased perceived exertion for a given training load
Impaired mood – may affect motivation to train
Reduced short-term memory capability

However, this approach is changing, as there is now a considerable body of evidence showing that sleep has a huge role in regulating many physiological functions. According to an issue of *Nature* published in 2005 we are 'Waking up to the importance of sleep' and 'A growing chasm separates the growing scientific understanding of sleep, and the widespread public assumption that it just doesn't matter' [4].

Health problems

There is mounting evidence that insufficient or poor quality sleep doesn't just compromise short-term physical performance, it is also associated with a host of serious health problems including weight gain, insulin resistance, type-2 diabetes and cardiovascular disease [5,6,7,8,9].

As little as six days with sleep duration restricted to four hours per night has been shown to alter the hormone profiles of healthy young people so dramatically that they effectively replicate those typically found in elderly or depressed individuals [2].

Other researchers have applied sleep research to athletic performance. A issue of *Psychiatric News* suggests that 'Sleep May Be Athletes' Best Performance Booster' [10]. And such has been the interest in sleep and sports performance that an entire issue

Jargonbuster

Body mass index
A measure of 'fatness', defined as weight in kilos divided by height squared in meters

Actigraph
A small electronic device, worn by an individual, that records and reports levels of activity as well as calories burned, limb movements and sleep levels

of *Clinics in Sports Medicine* has been dedicated to this subject and published in a book format as *Sports Chronobiology* [11].

The New England Journal of Medicine described sleep as 'a new cardiovascular frontier', highlighting the cardiovascular implications of normal and disturbed sleep[12], and recent research has shown that sleep deprivation can reduce cardiovascular performance by 11%, slow glucose metabolism by 30-40% and result in other changes that indicate possible accelerated ageing [6, 13, 14].

Hormones and sleep

Sleep deprivation is associated with a series of hormonal changes involving ghrelin and leptin (*see box*). In particular, restricted sleep has been associated with reduced leptin levels, increased ghrelin levels and elevated **body mass index** [15].

These hormonal changes can lead to increased hunger and appetite, making it more difficult to achieve the low body fat levels required for success in many sports. In one study, two days of restricted sleep resulted in an increased appetite of calorie-dense high carbohydrate foods, including sweets, salty snacks and starchy food, by 33-45% [6].

The quality of sleep is as important as duration. Sleep fragmentation due to fidgeting, restless legs or difficulty getting off to sleep can all combine with reduced sleep duration to contribute to sleep deficiency. Studies have also shown that sleep debt is cumulative, so even small amounts of sleep shortfall on a regular basis can accumulate to levels sufficient to compromise health and performance until that sleep debt is repaid [11].

Sleep and activity

Sports scientists working with coaches are beginning to use high technology **actigraph** devices to help monitor and improve sleep in athletes [16]. Although it is commonly believed that exercise improves sleep quality, there is little in the way of scientific evidence to support this notion. Whilst some exercise may improve sleep in sedentary populations, sleep disorders are common in elite athletes and sleep disruption becomes more

Measuring sleep debt

Several tests exist to quantify sleepiness and sleep debt. Tests like the Stamford Sleepiness Scale rate the likelihood of falling asleep while doing activities such as driving through to reading a book or sitting quietly in a dark room, and could be a useful addition to a training diary. By carefully noting sleepiness scores and correlating them with physical performance, athletes may be in a better position to decide whether an extra hour in bed may have a superior training effect than doing an extra training session.

More accurate tests of sleepiness involve sitting in a darkened room while brain wave activity is measured. Using this kind of test, it is possible to accurately measure 'sleep latency', which is the scientific term for the length of time it takes to go from full alertness to the moment of sleep.

For those athletes who have the time, it may be useful to replicate some of the experiments that attempt to quantify sleep debt by having subjects lie in dark soundproofed rooms for 14 hours each night. At the start of these studies many people sleep close to 14 hours, and only level out at a typical 8.5 hours sleep or so once the sleep debt has been repaid.

common with increased training volume [17] Athletes often report limbs that 'can't stop running' much in the same way that a racing mind can disturb sleep in stressed executives.

Periodic limb movement or 'restless leg syndrome' is a well known cause of disturbed sleep, and indicates a link between nutrition and sleep quality that goes far deeper than caffeinated beverages, alcohol or large meals at night reducing the quality of sleep.

There are, in fact, many nutrients within food that can help reduce the time taken to fall asleep, while others have a more complex relationship – *eg* where poor sleep may help create a deficiency, or a nutrient deficiency may result in poor sleep quality.

Poor sleep and suboptimal nutrition can both result in reduced exercise performance and in many cases it is difficult to find the initial cause of an accelerating downward spiral. This is especially important because many studies have suggested that suboptimal nutrition status in important 'sleep'

Hormones and neurotransmitters linked to sleep

Melatonin – the 'sleep' hormone; levels are often reduced in those with poor sleep patterns;

Serotonin – brain neurotransmitter that contributes to the regulation of sleep, appetite, and mood. People experiencing depression or anxiety often have a serotonin deficiency; poor sleep lowers serotonin levels;

Ghrelin – the 'appetite' hormone; levels increase with sleep debt along with cravings for sweet, fatty foods;

Leptin – the 'anorexic' hormone; reduced levels are associated with weight gain;

Testosterone – 'muscle-building' hormone; levels decrease with poor sleep;

Cortisol – the 'stress' hormone responsible for muscle breakdown; levels are increased during sleep deprivation, particularly in late afternoon and evening;

Prolactin – hormone produced by the pituitary gland that stimulates breast development and milk production; levels elevated with poor sleep.

minerals is far from uncommon.

In athletes, these problems can be compounded because the energy demands often place additional strain on these important nutrients. An over-reliance on cow's milk and milk products may also result in mineral and amino acid concentrations that are not conducive to good sleep.

Protein, tryptophan and sleep

Another nutrient that has a major impact on sleep is tryptophan, which is one of the essential amino acid building blocks of protein. Tryptophan is used directly to synthesise the brain neurotransmitter serotonin and the sleep hormone melatonin, and so effective is it at raising the levels of these hormones that it was used as an effective hypnotic for many years.

Tryptophan is well tolerated and without tolerance effects; however, it was banned for many years after an outbreak of **eosinophilia myalgia syndrome** was linked to the supplement (18, 19, 20). It was later concluded that this condition was not caused by tryptophan itself, but possibly by a contamination, and tryptophan has been allowed into supplements since

Jargonbuster

Eosinophilia myalgia syndrome
A blood condition characterised by tenderness and muscle aches, fatigue, cough, rashes, joint aches and shortness of breath

Neutral amino acids
Building-blocks of protein that carry no electrical charge

Magnesium – a vital 'sleep material'

Sleep disruption, high training volumes, exercise capacity and magnesium status are all related. A magnesium deficiency can cause periodic limb movement and 'restless leg syndrome', which can lead to poor quality sleep and significant sleep debt, and magnesium supplementation has been shown to be an effective treatment for periodic limb movement during sleep with or without restless leg syndrome [(21)].

However, this is a two-way process because chronic sleep deprivation or sleep debt has been reported to cause a further drain on magnesium levels, resulting in reduced exercise capacity [(22)].

It is possible that high training volumes and sleep deprivation may reduce magnesium status by a similar mechanism involving stress hormones. French researchers have described various mechanisms by which the stress caused by physical exercise may contribute to magnesium depletion[(23)]. These include the mobilisation of fatty acids for energy in endurance exercise, urinary losses and sweat losses. The good news, however, is that the reduction in exercise performance due to poor or disturbed sleep can be somewhat ameliorated by magnesium supplementation [(23)].

November 2005 albeit at very low doses.

However, partly due to the ban, much effort was focused on finding natural proteins high in tryptophan, particularly relative to the other large **'neutral' amino acids**. This is because tryptophan competes with other neutral amino acids for entry into the brain, so when trying to increase uptake into the brain (to boost serotonin and melatonin synthesis), it is the *ratio* of tryptophan that is important.

Much focus has been centred on the milk protein fraction alpha-lactalbumin, which is a natural protein source with the highest tryptophan content relative to other large neutral amino acids. Alpha-lactalbumin is found in human breast milk and cow's milk; however, the principle whey protein in cow's milk is beta-lactoglobulin, a low-tryptophan protein that is not found in human milk.

Efforts have been made over recent years to isolate alpha-lactalbumin for use in the human infant formula and it's now

'Contrary to popular belief, milk is not an ideal bedtime drink'

possible to produce alpha-lactalbumin on a commercial scale[24]. Researchers have therefore investigated its effectiveness in raising plasma tryptophan levels to see if it could be used in a similar way to tryptophan supplements[25]. Studies have shown that alpha-lactalbumin taken in an evening beverage reduces the subjective rating of insomnia and time awake during the night, improves sleep, and increases morning alertness and brain measures of attention[26,27].

Contrary to popular belief, milk is not an ideal bedtime drink; not only does it have a relatively low tryptophan content (because cow's milk contains protein fractions not found in human milk), it also contains large amounts of calcium, which can reduce zinc and magnesium uptake – important minerals for sleep and growth/recovery.

Low tryptophan levels in athletes

The use of protein powders and amino acid supplements for recovery and weight gain in athletic populations has rocketed in recent years. However, it is possible that the amino acid profile of proteins typically used by athletes and sports people could contribute to sleep disturbance by reducing the availability of tryptophan to the brain. Many of these protein powders are high in branched-chain amino acids and whey proteins high in beta-lactoglobulin. Both of these contain high levels of large neutral amino acids, which compete with tryptophan for absorption [28].

The general trend for low-carbohydrate/high-protein foods may also contribute to high levels of competing amino acids; carbohydrate consumption will typically result in an insulin response that drives branched-chain amino acids into muscle tissue, which effectively increases the plasma levels of tryptophan.

Summary

Sleep deprivation is a growing problem, and one that can significantly impair performance in athletes. It's also an area that's easily overlooked in the rush to fit training schedules around work and family commitments. If you suspect you're not getting all the sleep you need, addressing your sleep shortage may pay far more dividends than an extra training session here and there.

Sleep tips

- Avoid caffeine-containing drinks after 3pm as they can increase the time taken to fall asleep at bedtime;
- Avoid alcohol use in the three-hour period before bedtime. It may help you to fall asleep, but it can lead to disturbed sleep later in the night;
- Don't eat a large meal before retiring for the night. By the same token, don't go to bed hungry, especially if you've trained that evening as you may awaken later in the night with hunger pangs;
- If you're suffering from sleep problems, try to increase your intake of magnesium-rich foods (beans, peas, lentils, nuts, seeds, wholegrain breads and cereals, and green leafy vegetables); magnesium supplements may be also useful;
- Make sure your bed is comfortable; experiment with mattresses and pillows to increase sleeping comfort;
- Keep your bedroom well ventilated, quiet and cool;
- Go to bed when you're sleepy/tired, not when it's time to go to bed by habit;
- Take the time to wind down before bedtime. Don't get involved in any kind of anxiety-provoking activities or thoughts in the 90 minutes before bedtime;
- Try getting an extra hour's sleep every night for two weeks and see how your performance improves.

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Don’t stress! – using HRV data to optimise rest and recovery

At a glance:

- The concept of heart rate variability is summarised;
- The physiological and physical effects of fatigue and evidence for rest and recovery are presented and explained;
- The use of daily stress and recovery analysis to enhance endurance performance is outlined and examples given.

Heart rate variability is an exciting new tool that can be used to analyse and assess whether athletes are achieving adequate rest and recovery to avoid injury, illness or risk of overtraining, so that endurance performance is optimised. Eddie Fletcher explains.

Review of heart rate variability and cardiovascular fatigue

Measurement of the beat-to-beat interval of the heart clearly shows that heart rate is not constant but alters from beat to beat. This is known as heart rate variability (HRV). At rest this beat-to-beat interval fluctuates with the breathing cycle – it speeds up during inhalation and slows down during exhalation.

This variation is due to the attenuation of the **parasympathetic activity** to the heart during inhalation. Heart rate is regulated predominantly by the autonomic nervous system (ANS). The ANS describes the nerves that are concerned with regulation of bodily functions; these nerves function without consciousness or volition. The autonomic

Jargonbuster

Parasympathetic activity
Activity which slows down the heart beat

Cardiac autonomic modulation
Regulation of the heart which occurs automatically

nerves comprise sympathetic and parasympathetic nerves; sympathetic nerves excite the heart, increasing heart rate and parasympathetic nerves reduce heart rate.

Measurement of HRV for use in monitoring training and recovery involves analysis of the beat-to-beat variation. By accurately measuring the time interval between heartbeats, the detected variation can be used to measure the psychological and physiological stress and fatigue on the body during training. Generally speaking the more relaxed and unloaded (free from fatigue) the body is the *more* variable the time between heartbeats.

HRV data can indicate the impact of fatigue due to prior exercise sessions, hydration levels, stress and even the degree of performance anxiety, nervousness or other external stressful influences. Studies have shown that it varies within individuals according to size of left ventricle (inherited trait), fitness level, exercise mode (endurance or static training) and skill (economy of exercise)[1]. Body position, temperature, humidity, altitude, state of mood, hormonal status, drugs and stimulants all have an effect on heart rate and HRV[1] as do gender and age.

Stress is associated with increased sympathetic tone of the ANS whereas recovery is associated with increased vagal tone of the ANS – *ie* a continuous low-level flow of impulses down vagal nerves that induces a maintained slowing of the heart under resting conditions. The vagal nerve is one of the many nerves that carry messages to and from the brain. One of the main functions of this nerve is to monitor and control the

Cardiovascular fatigue

- Physical training with incomplete recovery can produce significant fatigue. Studies of cardiovascular responses show that there is a sympathetic and a parasympathetic form of fatigue;
- In short there is a cardiovascular form of fatigue which HRV can detect [2];
- There is also evidence to suggest that when recorded overnight, HRV seems to be a better tool than resting heart rate to assess accumulated fatigue and that HRV may be a valuable tool for optimising individual training plans[2,3].

activity of internal organs such as the heart and stomach.

Cardiac autonomic modulation is diminished in an overtraining state[4] as well as after a hard training period[2] and a simultaneous shift in favour of sympathetic (increasing heart rate) over parasympathetic (reducing heart rate) dominance occurs in the autonomic balance. Overtraining and recovery analysis looks at the balance between low and high frequencies within the heartbeat.

Typically HRV measurements demonstrate a significant and progressive decrease in parasympathetic indices during long-term heavy training followed by a significant increase during resting. The indices of sympathetic activity display the opposite trend. Sports-specific assessment prior to entering a long-term training plan using HRV has been demonstrated to be a useful tool[5,6].

'HRV data can indicate the impact of fatigue due to prior exercise sessions, hydration levels, stress and even the degree of performance anxiety, nervousness or other external stressful influences'

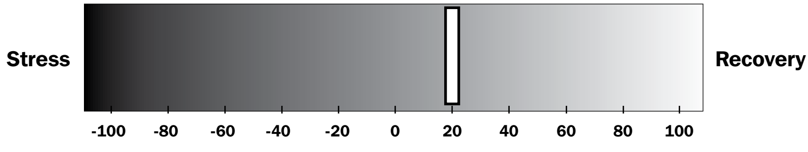
Why is it important to recover?

Overtraining is an imbalance between training/competition and recovery. Additional non-training stress factors and monotony of training may also contribute to overtraining syndrome. While short-term overtraining can be seen as a normal part of athletic training (HRV does not seem to be affected[7]) long-term overtraining can lead to a state described as burnout or overtraining syndrome[8].

Well-timed rest is one of the most important factors of any training programme. The effects of training sessions can be negligible or even detrimental if insufficient rest and recovery is built in. HRV measurements demonstrate a significant and progressive decrease in parasympathetic activity during long-term heavy training, which is followed by an equally significant increase during rest. Sympathetic activity shows the opposite trend.

This cardiac autonomic imbalance suggests that HRV is a useful parameter to detect overtraining and under recovery in athletes. During training, performance temporarily decreases but begins to rise during recovery. After a certain amount of time, performance rises above the pre-training level because

Figure 1: Stress/recovery index showing relative recovery (+20)



the body is preparing to handle the next training load better than before.

If the body does not receive the next training load within a certain period of time any performance gain begins to slowly decrease. However, if the next high-intensity session is held before the body has recovered from the previous one performance will remain lower than it would have been after full recovery. Continuous hard training with insufficient recovery will slowly lead to lower performance and a long-term state of overtraining. When overtrained, even a long period of recovery may not be enough to return performance to the original level.

The body needs time for recovery after a single high-intensity session, or a hard training period of several days, or even after a low-intensity but long training session. Without rest, adaptation to the training load will not occur.

The 'overload' principle is an important aspect of training and can be quantified by training load, duration, frequency and rest. However, application of excessive training stress or too many training sessions can result in exhaustion of the body's physiological system. Numerous studies have demonstrated that overtraining from long-term stress or exhaustion is caused by a prolonged imbalance between training and other internal and external stressors and recovery.

How does HRV stress/recovery analysis work?

The ANS reacts quickly to changing conditions. Many changes in physiological functions and especially in the autonomic nervous system function are reflected in our heart. Heartbeat measurement and analysis of heart rate reactions and HRV can provide significant information on body processes.

Beat-by-beat heart rate data contains much more information than just actual heart rate. Different types of reactions and changes in the heart rate contain embedded physiological information. By analysing HRV it is possible to verify that athletes are able to recover during the working day, between training sessions and especially during the night. In this context, stress can be defined as a physiological state of a heightened level of ANS function that is not caused by immediate physical demands. Accordingly, the HRV method is not able to specifically identify individual stressors but rather indicates the cumulative effect of different sources of ANS stress (*eg* lack of sleep, poor recovery from physical training, medication etc).

‘By analysing HRV it is possible to verify that athletes are able to recover during the working day, between training sessions and especially during the night’

Some heart rate monitors (*eg* models from Polar and Suunto) use HRV measurement as a feature to assess training load and overtraining based on individual heart rate response enabling the user to optimise their training load and recovery time (for a scientifically balanced view of HRV the reader is referred to an excellent review paper ‘Heart Rate Variability in Athletes’(1)).

What are the benefits of measuring recovery?

There are a number of benefits of measuring how much recovery has taken place. These include:

- Detecting early signs of overtraining or illness;
- Optimising training load by finding the balance between training load and recovery;
- Providing evidence-based support for critical coaching decisions;
- Recording individual baseline values *eg* during off-season when the body is fully recovered;
- Checking the recovery status during hard training periods;
- Checking recovery status when subjective feelings and fitness levels indicates poor recovery;
- Making sure that the body is recovered sufficiently before a new hard training period.

Figure 2: Interpretation of stress and recovery during the night (1)

No stress reactions detected during the night; athlete is well recovered

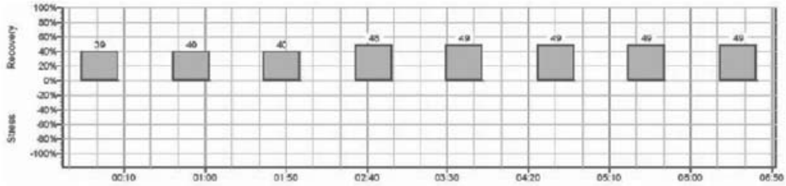


Figure 3: Interpretation of stress and recovery during the night (2)

Stress only present during first sleeping hours, after which good recovery

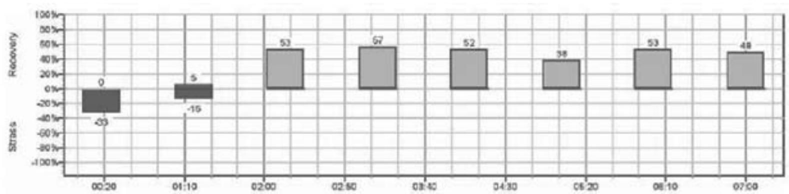


Figure 4: Interpretation of stress and recovery during the night (3)

Stress is present during whole night; an increased risk of overtraining – more rest needed

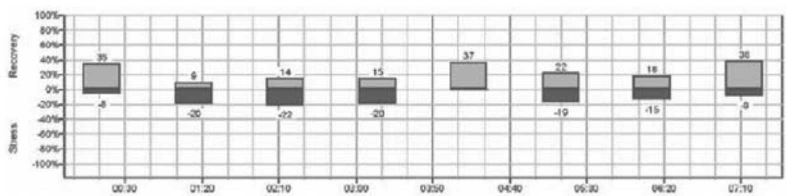
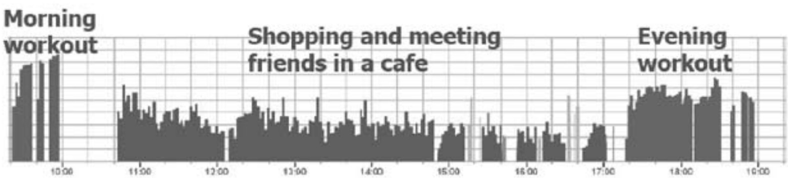


Figure 5: Shopping during the day – poor recovery



Using software such as that from Firstbeat Technologies, a recovery test is usually done as an overnight measurement so that the effect of external stressors can be minimised. It is also advisable to do some daily stress measurements to look at overall lifestyle stress. The selected time interval should also be standardised so that the results of different measurements can be compared individually. The first sleeping hours are often the most sensitive for recovery analysis (*eg* if you go to bed at 10-11pm, analyse from midnight to 4.00am).

Stress and recovery index – some examples

Stress and recovery in the Firstbeat Technologies software are represented on a scale from -100 to +100 (*see figure 1*). The stress and recovery index is the balance between stress and recovery. In the following diagrams 'dark' represents stress reactions whereas 'light' represents recovery reactions.

'It is advisable to do some daily stress measurements to look at overall lifestyle stress'

The intensities of the stress and recovery reactions are influenced by heart rate, heart rate variability and respiration rate, and can be considered as sensitive markers for detecting under-recovery and overtraining in sports.

Figure 3 shows when stress is present only during the first sleeping hours before the recovery reactions start to occur (therefore no risk for overtraining). Figure 4 shows stress reactions present during the whole night, indicating an increased risk of overtraining and that more rest is needed.

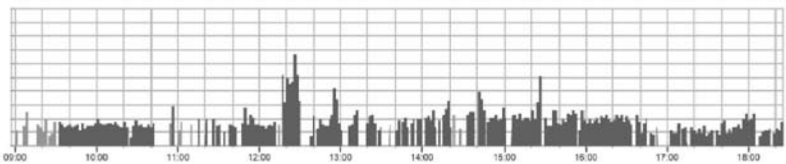
What are the benefits of measuring daily stress?

As with recovery, there are several benefits of measuring daily stress. In particular, daily stress monitoring can help athletes to:

- Maximise recovery between training sessions;
- Learn how different daily routines enable and limit recovery;
- Observe the effects of training at high altitude;
- Assess how travelling and jetlag affects recovery after competition/training;
- Repeat the daily stress recordings and observe how changes in daily routines affect stress and recovery;

Figure 6: Napping and reading during the day – good recovery

Figure 7: Full working day stress index for James



● Check for social and psychological stressors that influence recovery and manipulate daily routines for arrangements to minimise stress during the day.

Practical applications of daily stress measurement

Figures 5 and 6 show the balance between stress and recovery during the daytime period after a morning workout and before an evening workout. Figure 5 shows that shopping did not enhance recovery between two training sessions because stress reactions were detected during the whole time period between training sessions! However, taking a nap and relaxing at home enhanced the recovery reactions, preparing the body for the next workout (*figure 6*).

Working routines and daily stress index

Having carried out a large number of these tests, it is very clear that the largest influence on daily stress and recovery are work, family and emotional stressors with some individuals rarely

Figure 8: Overnight log of the recovery for James stress index showing poor recovery

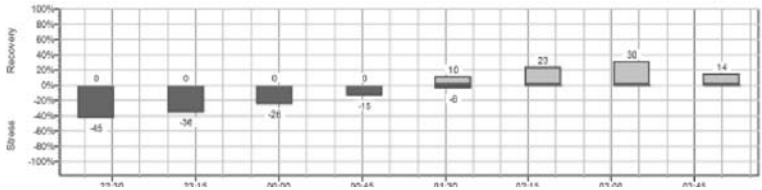
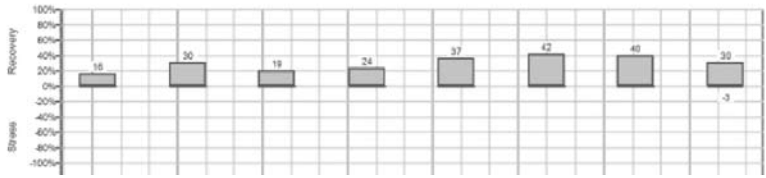


Figure 9: Overnight recovery log after a week away from work – 100% recovery



recovering from normal daily activities. For example, figure 7 shows the full working day stress index for James, a busy professional, while figure 8 is the overnight log of the recovery stress index showing very little recovery.

Now compare this with figure 9, which shows James' overnight recovery log after a week away from work, but having climbed Mount Kilimanjaro just three days previously! His recovery stress index scored +100, which meant he was fully recovered.

Conclusion

HRV is a relatively simple, but effective, tool for regular checks of progress during endurance training programmes. Overtraining or under recovery are real issues that athletes and coaches alike need to consider. It is also evident that the stress of normal everyday activities exerts a larger influence on training and race performance. Seemingly relaxing activities such as shopping may impose more stress rather than help recovery. Taking a nap, reading a book or listening to music appear to be excellent de-stressors. Overload periods need to be used with caution and additional rest periods or reduced intensity training sessions introduced to ensure athletes are optimising their training and recovery time. Close to a competition, monitoring of taper activities can be undertaken to ensure that the athlete competes in a fully recovered state. Heart rate variability monitors and associated software are powerful tools for athletes and coaches, providing useful information which can be used to adjust training programmes to best effect.

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Durational-intensity-recovery: a new training concept

At a glance:

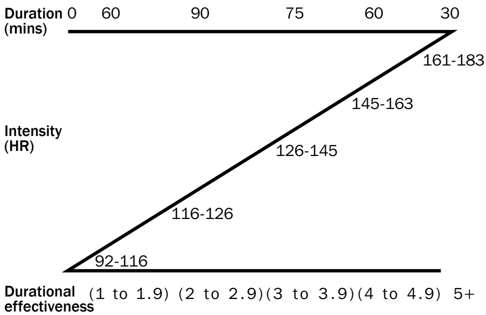
- The concept of heart rate variability, cardiovascular fatigue and rest and recovery are briefly reviewed;
- The duration-intensity-recovery line and training concepts are explained and presented.

In the previous article, Eddie Fletcher outlined the use of heart rate variability to enhance athletic performance, and to assess the quality of rest and recovery. In this article he explains how to combine these concepts to optimise physiological adaptation for endurance performance and to avoid overtraining by using the 'durational-intensity-recovery line'.

If you measure the beat-to-beat interval of the heart, it soon becomes apparent that heart rate is not constant but alters from beat to beat. This is known as heart rate variability (HRV). At rest this beat-to-beat interval fluctuates with the breathing cycle – it speeds up during inhalation and slows down during exhalation.

The measurement of HRV for use in monitoring training and recovery involves analysis of the beat-to-beat variation. By accurately measuring the time interval between heartbeats, the detected variation can be used to measure the psychological and physiological stress and fatigue on the body during training. Generally speaking the more relaxed and unloaded

Figure 1: Duration-intensity-recovery line for a specific athlete showing the duration of training in heart rate ranges and the numerical recovery period associated with each level



Scale of durational effectiveness levels
(recovery time – depends on the time spent at each level):

Scale	Recovery time in hours/days
1-2	3 hours to 1 day
2-3	1 to 2 days
3-4	1 to 4 days
4-5	2 to 7 days
5	7 days +

Level 5 is a 'durational breakpoint' inducing significant cardiovascular fatigue but note that durational breakpoint occurs whenever a session is beyond the intended durational effectiveness level for any session.

(free from fatigue) the body is, the more variable the time between heartbeats.

Physical training with incomplete recovery can produce significant cardiovascular fatigue, which HRV can detect[1]. There is also evidence to suggest that, when recorded, overnight HRV seems to be a better tool than resting heart rate to assess accumulated fatigue and that HRV may be a valuable tool for optimising individual training plans[1,2].

The duration-intensity-recovery line

The effectiveness of training in terms of physiological adaptation, cardiovascular fatigue, and therefore the need for rest and recovery is duration and intensity dependent. High-intensity training is by its nature short in duration and low-intensity training is longer duration. This leads to a concept of a 'duration-intensity-recovery guideline'.

The duration-intensity-recovery line is an athlete-specific 'Z diagram' that links duration (in minutes) with intensity (by heart rate and percentage of VO_2max) and cardiovascular fatigue (using a numerical recovery scale). This fatigue is calculated from a sport-specific maximal fitness test on an individual athlete, which uses HRV technology. See figure 1 overleaf.

The duration-intensity-recovery line is a flexible tool that attempts to answer the questions – How long should I train for? How hard should I train and how long do I need for recovery? Breaking the duration-intensity-recovery guideline for any session will hasten the approach of cardiovascular fatigue, lengthening rest and recovery periods needed and increasing the risk of overtraining and reduced performance.

When working with the duration-intensity-recovery line it is important to factor in and recognise the psychological condition of an individual athlete together with environmental conditions such as heat, cold, humidity etc. Psychological stress has a significant effect on cardiovascular fatigue, and the stress of normal everyday activities exerts a larger influence on training and race performance than is currently realised.

It may seem obvious that the effectiveness of any training plan is duration, intensity and recovery dependent, but is it? One of the key issues to address is how much time an athlete can spend at a particular intensity before the session induces more cardiovascular fatigue than intended, thereby reducing the effectiveness of the training and increasing the recovery period needed between sessions.

For example, suppose an athlete trains for 45 minutes at intensity X. Is the training effect and recovery the same if the athlete trains for 60, 75 or 90 minutes at the same intensity? Clearly not, but many believe it is. Some of the misunderstanding is from the interpretation and application of standard tests, which identify thresholds for training zones linked to heart rate, pace and lactate readings – tests which in themselves are fine but lose something in translation.

These tests do not identify the cardiovascular fatigue that builds up over time, the effective duration-intensity-recovery for any particular session or how each subsequent session should be adjusted to ensure adequate recovery.

‘One of the key issues to address is how much time an athlete can spend at a particular intensity before the session induces more cardiovascular fatigue than intended’

Duration-intensity terminology

The concept of duration-intensity-recovery also introduces ‘durational effectiveness’, ‘durational breakdown’ levels and a ‘durational collapse’ point:

● **Durational effectiveness** denotes the recovery period needed in hours or days following a training session where cardiovascular fatigue is increased significantly and which requires increased recovery or a lower duration-intensity-recovery session to compensate; durational effectiveness levels are on a 1-5 scale with each level scaled in tenths. *The values for each level are athlete-specific and derived from test data using HRV*;

- **Durational breakdown** level is the limit at which severe cardiovascular fatigue sets in – *eg* overtraining, maximal endurance efforts or the point at which a planned session exceeds its intended durational effectiveness. The need here is for prolonged rest and recovery;
- **Durational collapse** point is the limit of physiological performance. It is the point at which the body cannot continue to perform (*eg* the 'wall' in marathon running) and is associated particularly with long endurance efforts.

Duration-intensity-recovery line in practice

The start point for explanation of the duration-intensity-recovery line is to delve into an analysis of a traditional approach and then compare it against a duration-intensity-recovery line for a particular athlete.

A standard rowing aerobic endurance session is 3 x 6,000m (90 seconds rest between intervals) at 18 strokes per minute using a standard Concept 2 indoor rowing machine. The perception is that this type of session can be rowed at a set power percentage of an all-out 2,000m effort or at a heart rate established by a standard rowing step test linked to a lactate reading. Let's consider a real athlete:

Athlete's perception

This session can be rowed at a pace (mins:secs) per 500m equating to 60% of the power of a 2,000m maximal effort, with blood lactate reading of 2-4mmols and recovery over a period of hours, up to 24 hours.

Athlete's reality:

Interval	Stroke rate	Max HR (bpm)	Lactate (mmol)	Pace per 500m
1	18	165	1.87	2.02.1
2	18	174	3.62	2.02.1
3	18	181	6.82	2.01.1

How does this look on a duration-intensity-recovery line and what is the durational effect level?

Duration (mins)					
0	2	15	40	60	76
Intensity (HR)					
-	146	156	170	175	181 (Average 163)
Recovery (durational effectiveness level*)					
0	2	3	3.9	4.5	5+
* established from a test of the athlete					

Our athlete's session was at the lower limit of the intended training effect until the end of the first interval (2mmol lactate) and after 40 minutes was beyond the recovery, durational effectiveness level 3-3.9 (because recovery within 24 hours was desired) and lactate parameters.

After 15 minutes the session was already at durational effectiveness level 3. By the end of interval 2 the session was at a durational breakpoint level for this session, level 3.9, and continued to rise during interval 3 into level 5. The time required for recovery was days, in a session believed to have a recovery period of only 24 hours!

While not all training sessions should be shorter, high intensity, at the expense of longer, low-intensity efforts, this session was more than 30 minutes longer than required to achieve the intended training effect and was extremely fatiguing.

Using the duration-intensity-recovery line, our athlete's session description would change to 3 x 6,000 m at 18 strokes, limited by a HR range of 136-155. The calculated duration-intensity-recovery line (following testing) for this athlete might look like this:

Duration (mins)					
0	60	90	75	60	30
Intensity (HR)					
-	111-123	124-136	137-155	156-174	175-198
Recovery (durational effectiveness level)					
0	1-1.9	2-2.9	3-3.9	4-4.9	5+

Using a duration-intensity-recovery line and durational effectiveness level methodology, a 3 x 6,000m session for this athlete should have been rowed within a HR range of 136-155 to achieve the intended physiological training effect required (durational effect of 3-3.9).

Figures 2 and 3 illustrate what happened in reality and how the data should have looked using duration-intensity-recovery line to set the training intensities.

Duration-intensity-recovery line- short duration/ high intensity

To illustrate the top end of the duration-intensity-recovery line we can look at another standard rowing session known as a 30R20, 30 minutes at 20 strokes per minute but a maximum effort (high watts/pace), known as a power/endurance session (*see table 1*). This session, on a duration-intensity-recovery line, scales from 15 minutes up to 35 minutes depending on the fitness level of the rower.

Heart rate rises rapidly, near to maximum in the last few minutes and despite the short duration, the durational effect level is between 4 and 5. This necessitates a rest day followed by a long duration/low-intensity recovery session in the 2-3 durational effect level to give a 3-day recovery period for a top-class rower.

Figure 2: The reality of 3 x 6,000m intervals – notice steadily rising intensity

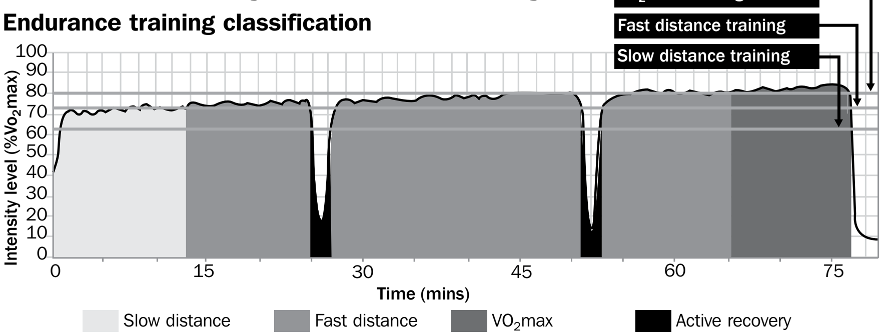
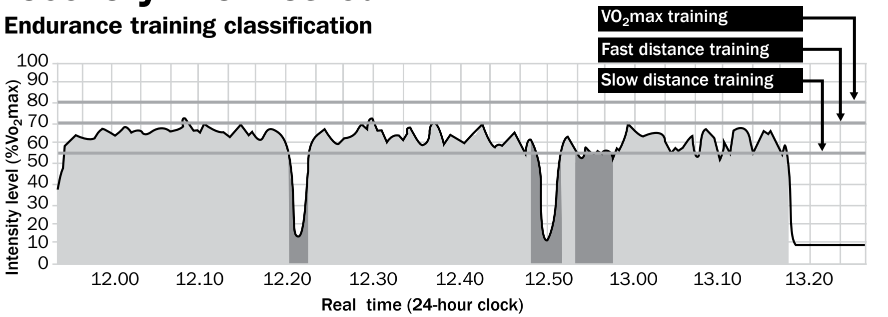


Figure 3: How the 3 x 6,000m intervals should have looked using the duration-intensity-recovery line method



Using the duration-intensity-recovery line for long endurance events

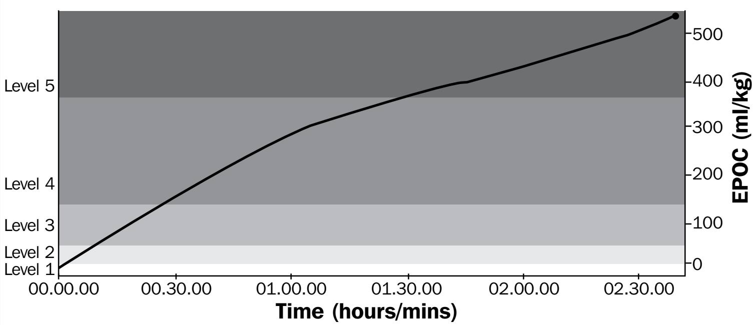
It is possible to calculate the required training intensity for ultra distance events such as marathons, triathlons (Olympic and Ironman distances), long cycling or swimming activities or any other long endurance event.

For a rowing marathon over the classic distance of just over 26 miles, the calculated maximum heart rate needed to ensure optimum performance is in the 4-4.9 durational effectiveness level. This is only the start point; as can be seen from the duration-intensity-recovery lines in this article, durational effectiveness level 4-4.9 gives an optimum duration for training purposes of up to 60 minutes.

Clearly rowing the full marathon distance, at a level heart rate in the duration-intensity-recovery 4-4.9 range and, at a power ratio to optimise performance will elevate the durational effectiveness level well into durational breakdown (level 5). It is possible to remain in level 5 for some considerable time; however, the longer an athlete spends in level 5, the longer the post-exercise recovery period will be (due to excessive cardiovascular fatigue) and the nearer he or she gets to total breakdown (durational collapse).

The marathon row below (*see figure 4*) was a British age

Figure 4: Durational effectiveness level for a marathon row (real data)



Time (mins) effectiveness point							
20	40	60	80	100	120	140	161
Heart rate (bpm)							
149	150	148	147	150	152	154	158
Durational							
3.8	4.8	5 rising	5 rising	5 rising	5 rising	5 rising	5 rising

group row of 2 hours 41 minutes 7.3 seconds – a wattage of 233W and pace per 500m of 1:54.5. The tested durational effectiveness heart rate at level 4.9 was 150bpm.

Looking at the data, an important point to recognise is that although heart rate and pace were held level, cardiovascular fatigue continued to rise with the duration. This is an obvious statement, but a point often missed by athletes and coaches. This athlete was in level 5 for close to 2 hours and recovery is counted in weeks rather than days!

Using the duration-intensity-recovery line in practice

Using the duration-intensity-recovery approach, training sessions may be structured to ensure optimum training effect and recovery. The first objective is to establish consistency in training by matching the durational effectiveness to heart rate, keeping variation to a minimum and ensuring correct recovery between sessions. It is important to watch for rising durational effectiveness over a series of sessions as this may indicate lack of recovery, illness or the beginning of overtraining.

Once consistency has been established, improvement may be indicated by a reducing durational effectiveness for similar sessions. If reduced durational effectiveness is observed consistently over time then a retest to establish a new duration-intensity line may be necessary so that any improvement may be consolidated into future training sessions.

‘It is important to watch for rising durational effectiveness over a series of sessions as this may indicate lack of recovery, illness or the beginning of overtraining’

Summary

This is quite a technical subject, so let’s just summarise the key points. The duration-intensity-recovery line is an athlete-specific Z diagram that links duration (in minutes) with intensity (by heart rate or % of VO_2max) and cardiovascular fatigue (by a numerical recovery scale). Moreover, it is also a flexible tool that attempts to answer the questions ‘How long should I train for?’ ‘How hard should I train?’ ‘How long do I need for recovery?’

The durational effective levels for a given heart rate depend on the athlete and are assessed by tests using HRV data. They are especially valuable because these levels denote the recovery period needed in hours or days. Durational breakdown level is the limit at which severe cardiovascular fatigue sets in, while durational collapse point is the limit of physiological performance

The data from the duration-intensity-recovery line shows that a shorter session at high intensity can produce the same effect as a long session at low intensity. Also, even when heart rate and pace are held constant, cardiovascular fatigue continues to rise with increased duration. Associated with duration-intensity-recovery are regular recovery tests to detect signs of overtraining or illness.

Heart rate variability analysis – a training tool you can't ignore

At a glance:

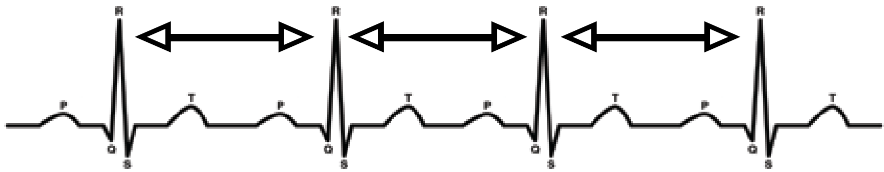
- An overview of the theory behind HRVA to determine training intensity and avoid overtraining is given;
- New evidence for the efficacy of HRVA and the link with ventilatory thresholds is presented;
- A step-by-step guide to using HRVA based on the latest research is given for athletes with suitable heart rate monitors who wish to implement the theory in their own training.

Heart rate variability analysis (HRVA) is fast becoming a versatile instrument for athletes and coaches. In this article Alan Ruddock provides further evidence for HRVA's efficacy and gives a step-by-step guide for sportsmen and women who wish to use HRVA as a monitoring tool to avoid overtraining and enhance response.

In endurance sports, several 'endurance markers' are used to monitor athletes, assess the effects of training and determine training intensity. The most frequently applied models are the **ventilatory threshold (VT)** and **respiratory compensation point (RCP)**. To identify these endurance markers, athletes normally undertake an incremental exercise test to volitional exhaustion, usually within, but not restricted to, an exercise physiology laboratory.

VT and RCP are identified using cardiopulmonary gas analysis equipment, which continuously measures oxygen and carbon dioxide concentrations and the flow of air inhaled and

Figure 1: Heart rate variability is measured by calculating the time between R spikes on an ECG trace



exhaled by athletes during exercise. As exercise intensity increases during the test, so does lactate and hydrogen ion production, and as the body attempts to 'buffer' the hydrogen, an increase in carbon dioxide occurs. The response of the physiological system is to increase **ventilation** (the total volume of gas being inspired and expired) to expel the carbon dioxide.

The point at which lactate begins to accumulate rapidly in the blood, causing an increase in ventilation is important to sport scientists because several studies have reported a strong correlation between these markers and endurance performance. For instance, an athlete's running speed at a lactate concentration of 2.5mmol/L^{-1} appears to be highly predictive of distance running performance at distance events such as the 10,000m and marathon[1].

The problem, however, is that blood lactate and ventilatory assessments are primarily restricted by laboratory protocols and expensive equipment that makes testing large numbers of athletes out in the field extremely difficult. Consequently, an inexpensive and non-invasive method to assess ventilatory thresholds has been proposed using HRVA.

HRVA is a non-invasive assessment of the **autonomic nervous system's** (ANS) control of heart rate. Heart rate variability reflects the time intervals between 'R spikes' of the 'QRS complex' displayed by an electrocardiogram (*see figure 1 for explanation*).

The ANS functions without consciousness or volition and

Jargonbuster

Ventilatory threshold
The exercise intensity whereby the first non-linear increase in ventilation and oxygen is observed

Respiratory compensation point The exercise intensity whereby hyperventilation occurs due to an increase in CO_2 production regulates numerous bodily functions via the sympathetic and parasympathetic nerves. Activity of the sympathetic nerves constricts blood vessels, decreases gastric movement, constricts sphincters and increases heart rate while parasympathetic nerves have the opposite effects. In heart tissue, sympathetic nerve endings are situated on the **myocardium**, while parasympathetic nerves on the **sino-atrial node**, atrial myocardium and **atrio-ventricular node**. Together these nerves act to control both heart rate and force of contraction.

HRV and ventilation

Several theories have been proposed to explain why HRV and ventilation are closely related. These theories propose that the ANS detects changes in blood pressure, cell chemistry, force sensors, local tissue metabolism and circulating hormones, which causes an appropriate response via the sympathetic or parasympathetic nerves in an attempt to maintain **homeostasis**.

The most studied theory in relation to HRV and exercise is that of respiratory sinus arrhythmia (RSA). RSA is an interaction between respiration and circulation whereby normal heartbeat and blood pressure vary secondary to respiration. The synchronicity can be seen in heart rate variability where R-R intervals are shortened during inspiration and prolonged during expiration.

During inspiration, the activity of the cardiac parasympathetic nerve is almost abolished, which results in a shortening of the R-R interval. In contrast, during expiration, the cardiac parasympathetic nerve reaches its maximum thus extending the R-R interval[2]. Think of it like this: when you inhale, you feel your muscles that control inhalation contract, which is when the sympathetic nervous system is predominant. When you expire you feel more relaxed – this is when the parasympathetic nerves are dominant. This link between respiration and HRV has led sports scientists to research into the effectiveness of HRV to detect ventilatory thresholds.

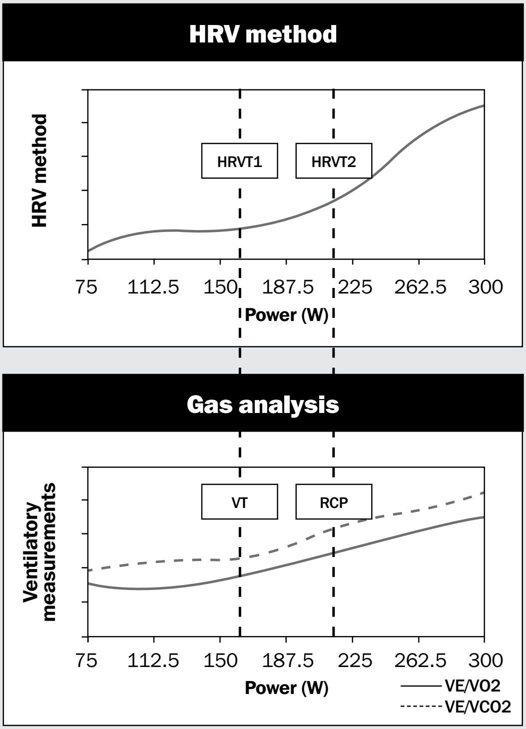
There are numerous ways to process/analyse HRV data and it is far beyond the scope of this article to explain how. Instead,

Jargonbuster

Autonomic nervous system (or visceral nervous system)
The part of the peripheral nervous system that acts as a control system, regulating various physiological functions in the body

Ventilation
Measurement of the total volume of gas being inspired and expired

Figure 2: HRV and ventilatory thresholds. Notice how the two heart rate variability thresholds (top) occurred near the same power output as the ventilatory thresholds (bottom)



interested readers are directed to the HRV standards and guidelines for clinical use for a detailed explanation[3].

However, while the study of HRV and ventilatory thresholds is a fairly new domain, back in the late eighties a piece of research was carried out that identified VT using breathing frequency (breaths per minute)[4]. Since then ventilatory thresholds have been identified using different methods with reasonable reliability.

Recently, researchers from France looked at the relationship between HRV and ventilatory thresholds[5]. Using both sedentary and athletic participants they found that the HRV method used to detect ventilatory thresholds was highly correlated with a gas analysis method for detecting ventilatory thresholds. In other words, the point at which VT was detected using gas analysis was close to the point at which the HRV method estimated VT. The researchers concluded that HRV was a useful tool for identifying ventilatory thresholds in both sedentary and athletic populations.

Other researchers have used different methods of HRVA analysis to detect ventilatory thresholds and despite differences in methods of analysis compared to previous studies, these groups have found HRV analysis to be a potentially reliable tool for detecting ventilatory thresholds.

For example, a group from France used a field-based incremental exercise test to determine whether ventilatory thresholds could be detected using HRV in professional French football players(6). These researchers used a commercially available Polar S810 heart rate monitor to record R-R intervals. After data analysis they found that HRV analysis underestimated VT by $0.25kmh^{-1}$ and RCP by $0.5kmh^{-1}$. Statistically, there were no significant differences between the HRV method and gas analysis in detecting either threshold. This led the researchers to conclude that the study provided an advance in exercise physiology since coaches now have the ability to assess ventilatory thresholds of athletes using inexpensive HR monitors.

‘In order for training to be effective, the body needs to have recovered from the previous training session but if too much time between training bouts has elapsed then gains begin to slowly reduce’

Despite these studies, there are still no universally agreed or simple and objective methods to determine ventilatory thresholds using HRV analysis. The good news, however, is that even though there are technical difficulties when using HRV to detect ventilatory thresholds, HRVA still provides a simple and effective method that will allow you to guide your recovery and training with more reliability than just subjective perception.

This method is based upon the principle that when athletes are overreaching, overtrained or even recovering from a training session, parasympathetic nervous system activity will be reduced. In order for training to be effective, the body needs to have recovered from the previous training session but if too much time between training bouts has elapsed then gains begin to slowly reduce. The idea then, is to monitor the parasympathetic nervous system using HRV; this method allows coaches and athletes to determine the state of autonomic function and therefore tailor future training sessions appropriately.

- Parasympathetic nervous system activity reduced – decrease training load;
- Parasympathetic nervous system activity increased – increase training load.

Pioneering Finnish researchers have shown that by using this method VT, maximal rate of oxygen uptake (VO_2max) and

Jargonbuster

Myocardium
Muscular tissue of the heart

Sino-atrial node
The heart's internal pacemaker

Atrio-ventricular node
Specialised heart tissue that conducts electrical impulses

Homeostasis
The maintenance of a stable internal environment within an organism

Natural logarithm
A mathematically derived number often used in statistics to make the interpretation of data more reliable

running speed at VO_2max can be improved by four weeks of training consisting of running sessions at either a low intensity (65% maxHR [maximum heart rate], duration 40-mins) or high intensity (85% maxHR, duration 30-mins)(7). The scientists took 30 recreational runners aged between 22 and 40 and split them into three groups, 10 in the HRV group (HRV), 10 in the training group (TRA) and 10 in the control group (CON).

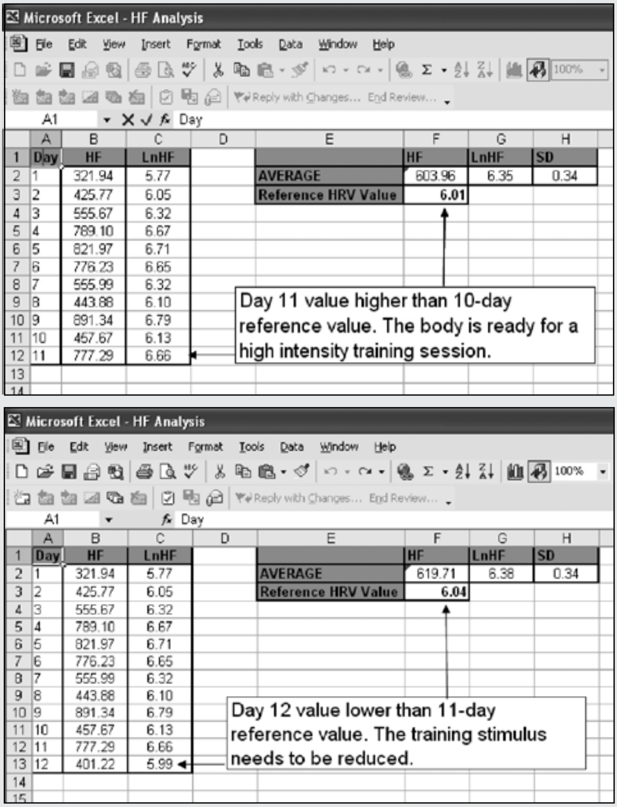
- In the HRV group the researchers recorded HRV on a daily basis. Before any training began for the HRV group, a 10-day rest period was implemented to collect baseline HRV measures. Then, during the intervention, if HRV dropped below the calculated reference value, the training load was reduced;
- The participants in the TRA group undertook a standard pre-planned training programme with no measure of HRV;
- Participants in the control group undertook no training.

The results showed that the HRV training group significantly increased their VO_2max (from 56 to 60mls/kg/min^{-1}), their maximal running velocity at VO_2max (from 15.5 to 16.4kmh^{-1}) and their running speed at VT (from 12.0 to 12.7kmh^{-1}). By contrast, only maximal running velocity at VO_2max significantly increased for the participants in the training group. Moreover, the participants in the HRV group undertook more training at a low intensity than the TRA group. The researchers concluded that whenever HRV is lowered, a lower training stimulus might be beneficial to gain a favourable response to endurance training.

Step-by-step guide to using HRV in your own training

The method that the Finnish researchers used to adjust training intensity using HRV is a relatively simple process that can be applied to guide your own endurance training. To do this you will need a Polar heart rate (HR) monitor that records R-R intervals (RS800 series, S810 series), Polar Precision Performance SW 4.0 software, which you can download for free from www.polar.fi. You will also need a spreadsheet package such as Microsoft Excel.

Figure 3: Excel charts showing examples of HF and Ln HF data displays and how they can used in conjunction with reference HRV values to plan training intensities



Day	HF	LnHF
1	321.94	5.77
2	425.77	6.05
3	555.67	6.32
4	789.10	6.67
5	821.97	6.71
6	776.23	6.65
7	555.99	6.32
8	443.88	6.10
9	891.34	6.79
10	457.67	6.13
11	777.29	6.66

	HF	LnHF	SD
AVERAGE	603.96	6.35	0.34
Reference HRV Value	6.01		

Day	HF	LnHF
1	321.94	5.77
2	425.77	6.05
3	555.67	6.32
4	789.10	6.67
5	821.97	6.71
6	776.23	6.65
7	555.99	6.32
8	443.88	6.10
9	891.34	6.79
10	457.67	6.13
11	777.29	6.66
12	401.22	5.99

	HF	LnHF	SD
AVERAGE	619.71	6.38	0.34
Reference HRV Value	6.04		

Step1 – The first thing you'll need to do is to set up your HR monitor to record R-R intervals, referring to your user manual to do this. Before you start using HRV to guide your training, you need to undergo a period of rest (no training) to collect resting baseline values; this period should last between seven and 10 days.

When you've decided on when this period will be, you're ready to start recording. The best time to record HRV is in the morning immediately after you have woken up and emptied your bladder. This will ensure you get the most reliable measure of parasympathetic activity as it is less likely that it will be affected by external influences such as physical activity, dietary intake or psychological stressors. If you regularly measure your morning HR, you need to record HRV when standing up for 5 minutes. This is so your HRV measure isn't 'swamped' by parasympathetic nervous system activity, which occurs when you lie down.

'The best time to record HRV is in the morning immediately after you have woken up and emptied your bladder'

Step 2 – After you've recorded this HRV data, import it into the Polar Precision Performance SW 4.0 software. Present the data as a *'curve of the HR values'* and then right click on the curve to display 'curve properties'. Under the HR tab, change the HR format to *'RR Intervals (ms)'*. This will display your RR intervals.

Step 3 – In the *'edit menu'*, select the entire exercise then click the right mouse button on the graph and select *'Error Correction'* in the dialog box. Now select 'OK' to remove any errors in the R-R plot.

Step 4 – Right click on the graph and choose the *'Selection Info'* option. This will bring up a dialog box with information regarding the HRV measure. Look for the *'HF (0.15 – 0.40 Hz)'* value and make a note of it. Let's assume (for the next step) you get an HF value of 321.94.

Step 5 – The next stage is to calculate the **natural logarithm** of the HF value. To do this open Microsoft Excel and in a cell type the command *'=Ln(321.94)'*. This will give you a result for the log of HF (HF Ln) of 5.77ms^2. Of course, you'll have your own HF values – simply substitute the example given above for the calculated HF (0.15-0.40 Hz) value displayed by the Polar software which you'll obtain from your own data.

Step 6 – Following your baseline period, you need to calculate the standard deviation of these values by typing *'=STDEV'* in Excel and then selecting all the reported HF Ln values for your baseline/rest period. Calculate the average of the HF Ln values and then subtract the standard deviation you've just calculated to obtain the daily reference value for HRV guided training. For each subsequent day calculate the average and standard deviation of the total HF Ln values; this will produce a moving day-by-day reference value.

Step 7 – When you record your HRV after your baseline period (*ie* when you begin training), you must then calculate HF Ln values using the method described above. If your HF Ln value is above the reference (baseline) value then it is likely that your body is rested and ready for a high-intensity training stimulus. If the HF Ln is below the reference value then you must reduce the training stimulus. Figure 3 shows you how this data will appear in Excel.

Conclusion

HRV analysis provides a non-invasive assessment of the parasympathetic and sympathetic nervous systems. Recent articles in the scientific community have shown that HRVA has the potential to be a versatile tool for athletes, coaches and sports scientists. Researchers are close to providing a simple and valid method for estimating ventilatory thresholds during field-testing by using HRVA but at the moment there exists no definitive method. However, it is possible for athletes and coaches to use HRV analysis to guide endurance training by estimating the level of recovery through quantifying parasympathetic nervous system activity. This method has been proved successful by Finish researchers and with some application, may well aid your training too!

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Advanced strategies for bringing your performance to a peak at just the right time

At a glance:

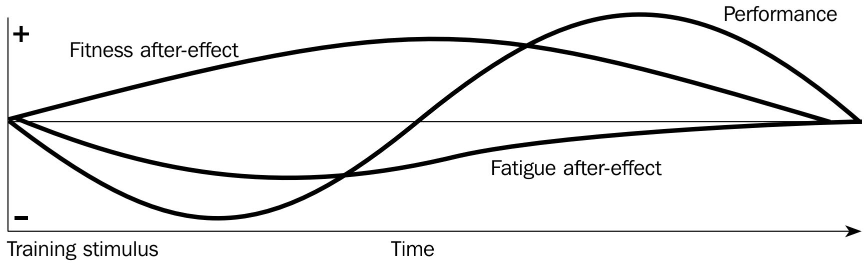
- The general principles of periodisation to reduce overtraining risks are explained;
- Appropriate periodisation programmes are given for beginner, intermediate and advanced level athletes.

Periodisation is a common training application based on Eastern European principles. It allows for variety of training, peaking for competition and working on technique and strength. James Marshall writes.

The traditional approach to periodisation is to move from high volume/low intensity to low volume/high intensity work. Periodisation maximises the effect of Selye's 'general adaptation syndrome' (GAS) theory, which argues that the acute effect of exercise is fatigue, followed by adaptation(1). If further training occurs within the fatigue window, then more fatigue occurs, with subsequent performance decrements, possibly leading to injury and overtraining. If further training occurs in the adaptation window, however, enhanced performance is the likely outcome. And, indeed, the chronic effect of exercise is performance enhancement.

Basic periodisation also moves from general to more specific work as the competition approaches. This technique, also known as linear periodisation (LP), is used to promote speed and

Table 1: Fitness-fatigue theory



power, with blocks of 4-6 weeks for working on each fitness parameter. However, if local muscular endurance is required, as for swimmers, runners, cyclists and triathletes, reverse linear periodisation (RLP) may be the better option[2].

RLP works on the basis of specificity. As the key requirement is for muscular endurance, the body needs to adapt to a greater demand placed on the endurance of the muscles, so building up to a greater level of repetitions is likely to be more beneficial than decreasing reps and increasing overall strength.

In a 15-week study carried out at the University of Arizona[2], 30 male and 30 female experienced weight trainers were trained according to three different periodisation strategies, as follows:

- Three five-week blocks working from 25 rep max (RM) to 20RM to 15RM (LP);
- Three five-week blocks working from 15RM to 20RM to 25RM (RLP);
- A daily undulating programme (DUP) in which the workouts changed on a daily basis from 25RM to 20RM to 15RM and back again.

All groups trained on two days per week, using three sets of leg extensions. At the end of the study, all three groups had made progress in muscular endurance, as assessed by the leg extension test, but the RLP group had made the largest gains (72.8% improvement compared with 55.9% and 54.5% for the LP and DUP groups respectively).

Adaptation for beginners

Inexperienced athletes need time to adapt to training loads and techniques, so LP and RLP may be the most suitable methods for them. Plyometric work, squats and Olympic lifts are both technically and physically demanding, and it takes time to build up the technique and skill to lift the kind of loads that force neuromuscular adaptation. Squatting, for example, requires ankle and hip flexibility, stomach and lower-back strength and correct breathing technique before leg strength is even tested.

This premise was used in a 12-week study comparing linear with non-linear periodisation (NL) in college American football players[3]. The players in each group performed four basic exercises: power clean, squat, push press and bench press. The NL group alternated between 3 x 4-6 reps of 70% 1RM and 3 x 2-4 reps of 90% 1RM. The LP group did three sets of 3-5 reps, 6-8 reps or 4-6 reps, depending on the exercise, all at 80% of 1RM.

At the end of the study period, the players were tested on bench press and squat. While there was no difference between the groups on the bench press results, the LP group increased their squat 1RM by an average of 13.8kg, compared with only 1.6kg in the NL group. The authors theorised that since all the players were accustomed to the bench press exercise but were relatively inexperienced in the squat, more significant gains were made with the latter. This study showed that gains can be made in-season using a basic periodisation strategy.

The problem with Selye's GAS theory is that it assumes a uniform response to training, in which initial fatigue is followed by fitness adaptation. By contrast, Bannister created the fitness-fatigue model *(see table 1, above)*, which suggests that different types of exercise generate different levels of response, and that each training bout gives rise to simultaneous fitness and fatigue responses, the latter exerting a detrimental effect on performance and the former a positive one[4]. The performance improvement comes later, when the fitness effect has outweighed the fatigue effect – *ie* the athlete has recovered – but the two effects are concurrent.

'Plyometric work, squats and Olympic lifts are both technically and physically demanding, and it takes time to build up the technique and skill to lift the kind of loads that force neuromuscular adaptation'

This model is different from the GAS theory because it allows athletes to use the different 'windows' after training to perform different training functions, and to schedule their training accordingly. Instead of treating all fatigue after training as the same, Bannister proposed that different sessions create varying levels and durations of fatigue and fitness.

Fitness and fatigue

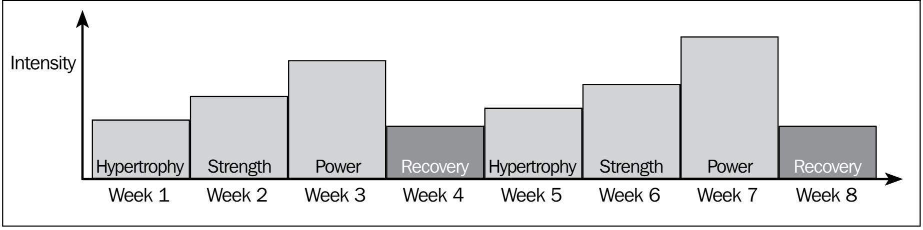
A session with maximal work (volume) will give rise to a lower, but longer lasting, overall fitness effect(5). The associated fatigue follows a similar pattern, setting in almost immediately. Maximal intensity sessions have larger – but less long-lasting – effects on fitness and fatigue, and a delay occurs before the fatigue is felt. The effects of maximal strength sessions fall between those of maximal volume and maximal intensity sessions, with fitness adaptations as well as fatigue delayed(6,7).

These delayed adaptations to strength training have been found to be greatest after a rest period. Strength work using eccentric-concentric exercise shows greatest adaptation in speed and strength after 21 days' rest, while strength work using eccentric or concentric exercises alone shows greatest adaptation 10-14 days later(8). But just try asking an athlete to take up to three weeks off before competing!

The varying effects of different types of workouts on fitness and fatigue have implications for scheduling training and for sequencing the order of weight training exercises within a session. Consider, for example, the use of complex training, where a near-maximal strength exercise, such as squats, is followed by a power/speed exercise, such as squat jumps. This type of training is based on the 'posttetanic potentiation effect', whereby there is a greater ability to produce force within the muscles immediately following acute resistance exercise. It has been proposed that this is due to an increase in reflex electrical activity in the spinal cord, which is likely to be apparent only in trained athletes.

Chiu *et al* compared the effects of a heavy warm-up (5 sets of

Table 2: Intermediate periodisation-weekly undulating programme for 8-week cycle



1 rep of 90% of 1RM squat) on squat jumps in trained athletes from explosive sports and recreational subjects[6]. While the recreational subjects showed a decline in posttetanic potentiation following the heavy warm-up, the trained athletes showed an increase.

So, while the immediate response to the exercise was fatigue for both parties, the trained athletes also experienced an immediate fitness effect, in that they were able to produce more power.

Trying to schedule workouts in a way that produces maximal fitness effects with minimal fatigue is difficult. However, it is the basis for 'intermediate periodisation' strategies.

Intermediate trainers use more intensive efforts including bounding, high loads and variations of exercises. Each week rather than each month has a specific purpose *(see table 2, above)*, with each new cycle of work increasing in intensity. The recovery week is necessary to allow adaptations to take place.

Within team sports, weekly schedules are easy to organise, as most matches are played once a week and sport-specific training takes place at regular times. By linking in with these weekly cycles, the coach can plan his technical/tactical sessions around the intensity of the players' conditioning, or the conditioning sessions can be placed before or after the technical sessions.

The concept of scheduling can be taken further by changing each workout on a daily basis (daily undulating programme, or DUP) so that no one factor is overemphasised[9]. This approach also allows sessions to be scheduled in such a way as to capitalise on the fitness effects from the previous session *(see table 3, overleaf)*. However, it is most useful in circumstances where

'Trying to schedule workouts in a way that produces maximal fitness effects with minimal fatigue is difficult - however, it is the basis for 'intermediate periodisation' strategies'

Table 3: Sample daily undulating programme (DUP) of 4 exercises

	Mon	Wed	Mon	Wed
Squat	3 sets 10 reps 70% 1RM	5 sets 5 reps 80% 1RM	6 sets 2 reps 90% 1RM	3 sets 10 reps 70% 1RM
Bench press	3 sets 10 reps 70% 1RM	5 sets 5 reps 80% 1RM	6 sets 2 reps 90% 1RM	3 sets 10 reps 70% 1RM
Lunge	3 sets 10 reps 70% 1RM	5 sets 5 reps 80% 1RM	6 sets 2 reps 90% 1RM	3 sets 10 reps 70% 1RM
Clean & jerk	3 sets 5 reps 70% 1RM	5 sets 3reps 80% 1RM	6 sets 1 rep 95% 1RM	3 sets 5 reps 70% 1RM

workouts are closely supervised. In my experience, getting athletes to adhere to a weekly schedule is difficult enough without introducing this level of complication. DUP has been shown to be effective for off-season strength development, possibly because it is simpler to administer when there are fewer competing demands on athletes[10,11].

Because it is important to keep sight of overall goals rather than individual sessions, tactical changes sometimes have to be made. For example, Rugby Union players may experience varying fatigue effects from a game played on Saturday. If it was a forward-dominated game, played in wet conditions, the front five may be physically and mentally shattered on the Monday, while the backs remain physically fresh. The coach must then either reschedule the planned workout for the front five or do something different, such as reducing reps or intensity, or organising a recovery session in the swimming pool.

Advanced workouts for élite athletes

Elite athletes with a high training age (*ie* who have been training for some time) perform advanced workouts that vary both in content and workload. While intermediate periodisation works on several different aspects of training at once, élite athletes may use ‘unidirectional training’, where they focus for several weeks on one aspect of fitness (such as strength), followed by a briefer focus on a different aspect, such as power. With this approach, known as ‘conjugate sequencing’, a four-week period of overreaching is followed by a two-week block with a change of emphasis to allow for supercompensation.

The concentrated block of training results in a 'long-term delayed training effect' (LDTE) of anything between four and 12 weeks, depending on the volume and intensity of the training. The two-week block should concentrate on speed and power.

The advantage of this system is that the athlete does not suffer as a result of the demands placed on their body by other training. It also offers a period of concentrated training on one aspect, allowing for overloading and a subsequently greater effect on fitness. It also allows for a lower overall work volume (not intensity) because only one aspect is being trained at a time.

Unidirectional training does, however, require an ability to tolerate heavy training loads without breaking down, which is why it should only be used by athletes with an advanced training age. Advanced short-term recovery methods should also be used to prevent breakdown in the overreaching cycle.

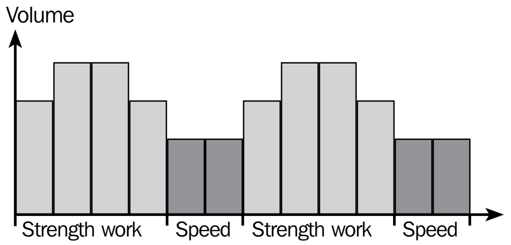
Short-term performance will suffer as a result of the overreaching part of the cycle, but the overall gains may be higher. Unidirectional training is difficult to use in sports with long seasons and very short off-seasons (such as Rugby Union, football and tennis) as the accompanying short-term decrements in performance will be unacceptable to most coaches (not to mention most fans). However, an off-season of three months can provide adequate time for this approach to work *(see table 4, opposite)*.

Sessions are planned as follows:

- Weeks 1-4 – strength. Four sessions a week strength, 2 sessions technical, 2 sessions speed/agility;
- Weeks 5-6 – recovery. Two sessions a week power, 4 sessions technical, 2 sessions speed/agility;
- Weeks 7-10 – strength. As weeks 1-4;
- Weeks 11-12 – recovery. As weeks 5-6.

While the emphasis of each block is on one aspect of strength/ fitness, that does not mean all workouts should be the same. Advanced athletes have a greater technical ability to perform the more advanced lifts, and require greater variety of exercises and intra-session sequencing to force adaptations within the

Table 4: Unidirectional training during a 12-week off-season



'It is important to remember that periodisation will not always lead to standardised, quantifiable results. Other factors, such as athletes' perceptions, non-training stressors, circadian rhythms and technical/ tactical issues will also have an impact on the outcome'

body and to stay mentally fresh. So contrast training, wave-loading, dumbbell/barbell/body weight/other apparatus exercises can all be sequenced into the four-week strength-training block.

It is important to remember that periodisation will not always lead to standardised, quantifiable results. Other factors, such as athletes' perceptions, non-training stressors, circadian rhythms and technical/tactical issues will also have an impact on the outcome.

In most team sport environments, the athletes are part-time, either employed or studying, and these additional stressors must be taken into account in the periodisation schedule. In a season-long study of female college basketball players, US researchers analysed the incidence of injury and illness in relation to the training load, measured according to Borg's rating of perceived exertion (RPE) scale of 1 (easy) to 10 (hard). They found the incidence of illness was not related to the athletes' training load, but to their mid-term and end-of-semester exam schedules.

Balancing training and recovery

It is important to balance training and recovery, with more intense training requiring longer recovery to allow for adaptation. It is also important for periodised training to be closely supervised by coaches who understand the concepts involved, to avert the risk of physical and mental overload leading to overtraining.

When considering the three different levels of strategies outlined in this article, it is crucial not to think of one as being better than the other, although one may be more appropriate than another. If you are just starting out, for example, it is not desirable or even possible to train like an élite athlete. All three strategies allow for intense quality workouts, with sport-specific training.

However, as training age increases, so does the body's resistance to existing stimuli and training methods. As the athlete's technical ability and strength improves, so does his or her need for greater variety of exercise to provide new stimuli.

Beginner athletes (which means those new to a particular sport or exercise discipline) will also have limited technical ability in the Olympic lifts. They will not be able to lift enough weight correctly to generate the power, and will risk injury by trying to do so incorrectly. For this reason, simpler lifts should be included in the programme until their technical abilities improve.

Also, beginner athletes will not be able to sequence the exercises in the same way as their advanced counterparts because where experienced athletes will be benefiting from an immediate post-exercise fitness effect, beginners will be experiencing fatigue.

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Is your training diary a load of nonsense?

At a glance

- The importance of determining training load is explained along with the limitations of heart rate monitoring;
- Three separate methods of determining training loads are presented and their applicability is discussed;
- Practical advice is given for sportsmen and women wishing to use these methods to monitor training loads.

Quantifying the training load of athletes in the ever-faithful training diary has always been of great importance to coaches. But according to Alan Ruddock, without some kind of record of the body's physiological response to exercise, it's hard to really assess an athlete's condition and determine whether he or she is undertrained, optimally trained or overtrained.

Measuring an athlete's training load through physiological monitoring provides the opportunity for the coach to build up a detailed training history, which should form the basis for any assessment of performance. For instance, using a training diary, it's possible to infer links between the volume of training and decrements in performance and make assumptions about the possible occurrence of the overtraining/overreaching syndrome.

Alternatively, the coach may wish to know what type, intensity, duration and frequency of training stimulus is optimal to develop maximal aerobic capacity (VO_2max). Using a past history of training load and physiological test results, it's possible to determine how much training is required to improve

VO_2max. Successful monitoring and assessment of training may then lead to improvements in performance.

Training load

A number of methods to quantify 'training load' have been used for training and monitoring in different sports, including athlete self-assessment of training sessions, simple calculations of volume and heart rate (HR) response methods. The commonest method now used for monitoring training load is '*Training Impulse*' or '*TRIMP*', which was formulated by Bannister in 1975. Since Bannister first introduced the TRIMP it has been modified several times to refine its use of HR data.

Although HR monitoring is both valid and reliable, problems can occur when using this information to interpret physiological responses. For example, the relationship between HR and **blood lactate** is linear at low to moderate speeds/power outputs but as exercise intensity increases, HR increases linearly but blood lactate rises exponentially – *ie* the various physiological responses occur that are not necessarily reflected in HR data alone.

To overcome this problem, Carl Foster introduced a **weighting** category based upon percentages of maximum heart rate to give a TRIMP score. He also used perceived rating of exertion (PRE) to provide an overall subjective assessment of a training session [1]. In a further development, a research group from Spain gave weightings to three physiological stages based upon analysis of inspired and expired oxygen and CO_2 [2].

Following an incremental exercise test to exhaustion, an analysis of oxygen and CO_2 gas flows in the body can reveal two distinctive changes in **ventilation**, which represent different physiological occurrences in response to an increase in exercise intensity (*see figure 1*):

1. The first identifiable point is the **ventilatory threshold** (VT) – it represents one of the body's initial responses to a change in **homeostasis** as a result of exercise;
2. The second identifiable point is the respiratory compensation point (RCP), which marks the exercise intensity at which heavy breathing is required to help remove metabolites from the body.

Jargonbuster

Ventilation
The total volume of gas being inspired and expired

Blood lactate
A by-product of energy metabolism during intense exercise and which can be used as a marker of endurance performance

Ventilatory threshold
The exercise intensity where breathing rate increases abruptly

Homeostasis
The maintenance of a stable internal environment within an organism

Weighting
The number that a quantity is multiplied by to make it comparable with others

The Spanish researchers tested eight national and regional level male runners to determine their VT and RCP. They then used the modified TRIMP to provide the following weighting factors.
Zone 1: Light intensity, heart rates below the exercise intensity that elicits VT; 1 minute of exercise in zone 1 is given a score of 1;
Zone 2: Moderate intensity, heart rates between the exercise intensity that elicits VT and RCP; 1 minute of exercise in zone 2 is given a score of 2;
Zone 3: High-intensity heart rates above the RCP; 1 minute of exercise in zone 3 is given a score of 3.

Example of calculation of TRIMP

An athlete performs a training session and spends:

- 32-mins in Zone 1
- 10-mins in Zone 2
- 4-mins in Zone 3

TRIMP = (32 x 1) + (10 x 2) + (4 x 3)

TRIMP = 32 + 20 + 12

Total TRIMP score = 65

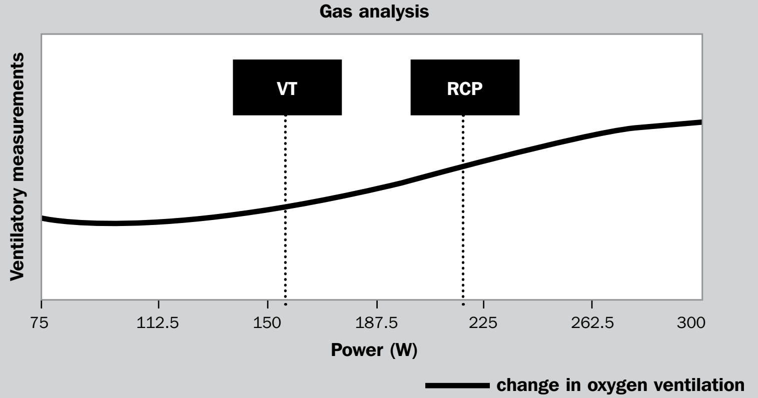
After determining the training zones the researchers gave HR monitors to all participants and asked them to wear the monitor each time they trained. The purpose of this was to determine the relationship between training load and running performance during the most important competitions of the season (*ie* national cross country championships). Training load was monitored each session over a six-month period.

Results showed that the athletes in this study spent most of their training time (71%) at low intensities (zone 1). The percentage of time training at moderate (zone 2) and high (zone 3) intensities was 21% and 8% respectively. In this particular group of athletes, there was a significant correlation between the amount of time they spent training in zone 1 and performance in both the short and long cross country races; the athletes who spent more time training at a low intensity (below VT) performed better in a high-intensity (30 minutes of continuous exercise in zone 3) race!

Five-zone TRIMP

In another study, British scientists recognised that training at higher intensities should be awarded larger weighting factors because of the greater physiological demand imposed by high-

Figure 1: Illustration of ventilatory threshold (VT) and respiratory compensation point (RCP)



Jargonbuster

Fractional elevation
The elevation in HR during exercise in relation to resting HR

OBLA
Onset of blood lactate accumulation, usually accepted as being a concentration of 4mmol/L

intensity training [3]. Using blood lactate and HR responses to a treadmill test and a concept known as the '**fractional elevation**' in heart rate, they arrived at a five-zone system that more accurately reflects the increased physiological stress imposed by high-intensity activity (*see table 1*).

Similar to previous TRIMP methods, the total time spent in each zone was multiplied by a weighting factor to calculate training load. The difference in this instance is that as exercise intensity increases, the weighting factor increases exponentially rather than linearly. In previous TRIMP methods low (zone 1) intensity exercise was given a weighting of 1 and high (zone 3) intensity a weighting of 3, a simple linear increase. The five-zone method gives high-intensity activity a weighting about seven times greater than low-intensity activity.

The researchers who developed this method gave eight male premier league hockey players a HR monitor and recorded their HR responses to training and competition from the start to the middle of the season. They found that those players who had a higher mean weekly TRIMP value had the largest change in VO_2max and velocity at **OBLA**, suggesting that the greater the training volume, the greater the increase in VO_2max and

Table 1: Training zones based upon the modified TRIMP (MHR = maximal heart rate)

Zone	% MHR	Weighting	Training Type
5	95-100	5.91	Maximal training
4	90-94	4.01	**OBLA training**
3	84-89	2.57	'Steady state' training
2	77-83	1.65	Lactate threshold training
1	64-76	0.84	Moderate activity

velocity at OBLA.

The *percentage changes* in VO_2max and velocity at OBLA were also correlated with the mean weekly time spent in high-intensity training (zones 4 and 5). This suggests that the more time spent training at a high intensity, the greater the improvements in VO_2max and OBLA. Interestingly, the researchers calculated how much weekly TRIMP value players needed to accumulate to maintain VO_2max and velocity at OBLA. They found that players needed a lower mean weekly TRIMP value to maintain VO_2max than OBLA and needed to spend less time engaged in high-intensity training to maintain VO_2max than OBLA.

These calculations are particularly useful to coaches when planning and monitoring training as they can ensure that each player is receiving a sufficient training stimulus to maintain or improve VO_2max and OBLA throughout the season. The major limitation to this study is that it only took into account endurance training when hockey training most likely comprises of speed and strength training too.

Intermittent sports training

Most sports, especially team sports, comprise a mix of three basic physical qualities, speed, strength and endurance. However, previous TRIMP systems have been limited to identifying the training load of endurance training and have not been able to account for other training loads using one

Box 1: Work Endurance Recovery method

The Work Endurance Recovery (WER) method for calculating training load is calculated using the following equation:

WER = CW/Endlim + ln(1+DCW/DCR)

In this equation:

CW = Cumulated work; the sum of the exercise durations completed at the required intensity. In endurance training this is the amount of minutes engaged in activity. For example, in a session of 4 reps of 15 mins running the CW would be 60 mins. A sprint session of 10 x 50 mins in 6.7 secs would equate to a CW of 67 secs and CW for a weights session would be the total amount of reps, *ie* 27.

Endlim = Endurance limit; determined during testing sessions. For endurance training it is the maximum time running at 85% of the participants maximal aerobic velocity (29.3 mins in the example given in table 2). For sprint training, it's the maximum time spent at 95% of the velocity at 50m (12.6 secs in example) and for strength training the number of repetitions at 85% of 1-rep max (6.2 in example).

Ln = natural logarithm; a mathematical term derived from the 'natural' number' e.

DCW = Duration of the cumulated work; This is the same result as CW in endurance and sprint training but expressed in seconds. In resistance training it is the sum of the time taken to complete each repetition (eg, if one rep takes 5 seconds and there are 27 reps, DCW = 5 x 27 = 135 seconds.

DCR = Duration of the cumulated recovery periods; This is the sum of the recovery periods occurring over the course of the session expressed in seconds. For example, if 3-minute recovery periods (180 seconds) are assigned to 3 sets of 3 different exercises, the DCR would be 180 x 8 = 1440 seconds.

single TRIMP method.

French researchers attempted to quantify the training loads of endurance, sprint and strength training using one single TRIMP method for use with intermittent sports training[4]. The Work Endurance Recovery (WER) method created by this team is based upon the theory that training-induced physical stress can by quantified in relation to an athlete's maximal work capacity. So rather than training loads being quantified in

Table 2: Examples of WER calculations

	Endurance Training	Sprint Training	Strength Training
Cumulated work (CW)	60 mins	67 secs	27 Reps
Endurance limit (Endlim)	29.3 mins	12.6 secs	6.2 Reps
Duration of cumulated work (DCW)	3600 secs	67 secs	53 secs
Duration of cumulated recovery (DCR)	720 secs	2760 secs	1440 secs
WER calculation	(60/29.3)+	(67/12.6)+	(27.5/6.2)+
	Ln(1+(3600/720))	Ln(1+(67/2760))	Ln(1+(53/1440))
Work Endurance Recovery	**3.84**	**5.34**	**4.47**

relation to physiological responses (*eg* blood lactate, HR or VO_2max and CO_2), it is based on 'fatigue occurrence', making it possible to monitor different training load types using a single equation (*see box 1*).

The researchers above compared the WER method with TRIMP methods to determine how accurately they measured training loads by asking participants to exercise until exhaustion in three separate sessions – one endurance, one sprint and one strength. They then assumed that each session provided a similar training load – *ie* around 33% of total volume each and because the WER equation calculates training load in relation to fatigue; the total work capacity of 100% divided by three sessions equates to about 33%.

They discovered that there was no difference between the calculated training loads of sprint or strength training regardless of which TRIMP method used. However, large differences in training loads were observed between endurance training and sprint/strength training; endurance session training loads were 2.5-2.8 times higher than sprint training and 5.1-5.5 times higher than the strength training. This confirmed that the TRIMP methods are incompatible when comparing training loads of different exercise modes. By contrast, when they used WER, they found that each session represented around 31 -35% of the cumulated training load indicating that there was no difference between the training sessions and confirming the group's hypothesis.

'The Work Endurance Recovery (WER) method is based upon the theory that training-induced physical stress can by quantified in relation to an athlete's maximal work capacity'

Despite some limitations relating to the determination of endurance limits, the major advantage of the WER method over TRIMP methods is that it allows the comparison of different training sessions on the same scale and is thus a good base for the development of monitoring training loads in intermittent sports.

Conclusion

If you want to calculate your TRIMP scores, choose a method most appropriate to your sport. For sports where you undertake only one type of training (*eg* running or cycling) then one of the TRIMP methods may be the most appropriate for you. The modified five-zone TRIMP is probably the best choice for monitoring training load in this instance because the test protocol and data analysis to determine the blood lactate curve is less complicated and time consuming than gas analysis used by the three-zone TRIMP. And while calculating the weighting factors using five-zone TRIMP is a little more complicated, these factors provide a far more accurate load calculation when exercise is intense.

If you participate in sports that requires a mix of two types of exercises or more such as track and field sprinting (which requires sprint training and weight training) or rugby (which requires endurance, sprint and weight training) then the WER method may be more appropriate for you. The testing can be conducted outside the lab, requires no sophisticated equipment and providing you follow the calculations accurately (it's probably easiest if you use a spreadsheet) the WER method is a good option to monitor training load across different types of exercise.

References

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