Beyond heart rate – rest and recovery for optimum endurance performance

Following his article 'Heart rate variability – what is it and how can it be used to enhance athletic performance' (issue 237), ***Eddie Fletcher*** *expands the debate by looking at the use of heart rate variability to analyse and assess whether athletes are achieving adequate rest and recovery to avoid injury, illness or risk of over training so that endurance performance is optimised.*

At A Glance

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

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 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.

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]

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 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. Then 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].

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. Whilst 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 program. 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[9].

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 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 heightened level of ANS function that is not caused by immediate physical demands. Accordingly 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).

Some heart rate monitors (*eg* models from Polar and Suunto) use HRV measurement as a feature to assess training load and over-training based on individual heart rate response enabling the user to optimize their training load & 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. These include:

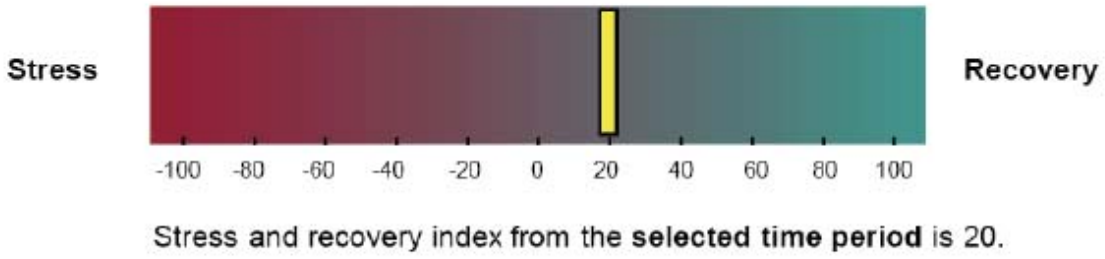
- Detecting early signs of overtraining or illness;
- Optimising training load by finding the balance between training load and recovery;
- Providing evidence based support for critical coaching decisions;
- Recording individual baseline values *eg* during off-season when the body is fully recovered;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

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 most the sensitive for recovery analysis (*eg* if you go to bed at 10-11 pm, 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). Stress and recovery index is the balance between stress and recovery. In the following diagrams 'dark' represents stress reactions whereas 'light' represents recovery reactions.

figure 1 – stress/recovery index showing relative recovery (+20)



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 2: interpretation of stress and recovery during the night

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

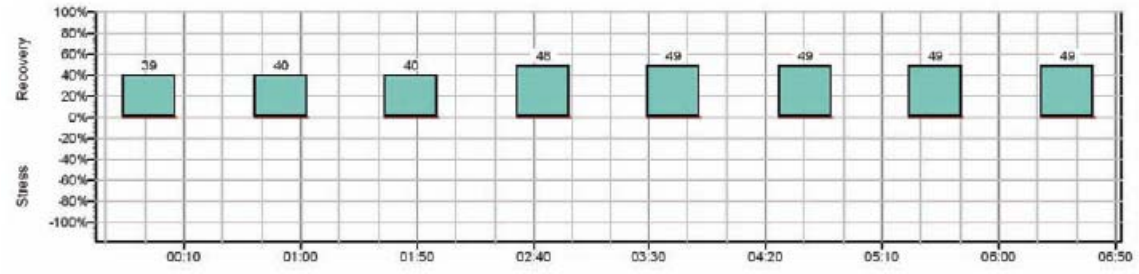


Figure 3 shows when stress is present only during the first sleeping hours before the recovery reactions starts to occur and therefore when there is no risk for overtraining, while figure 4 shows when stress reactions are present during the whole night, indicating an increased risk of over training and that more rest is needed

Figure 3: stress is present only during the first sleeping hours

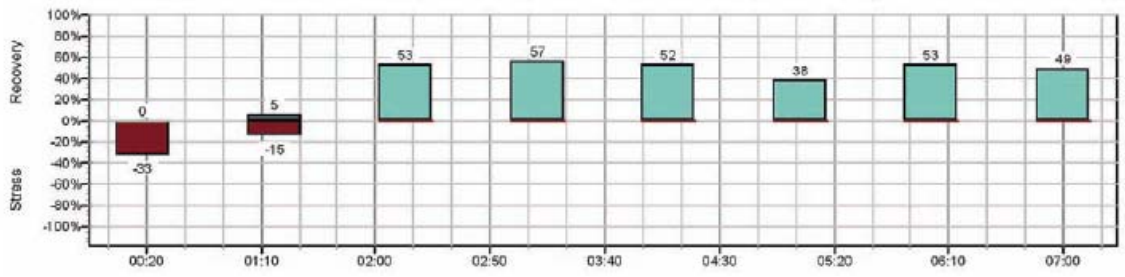
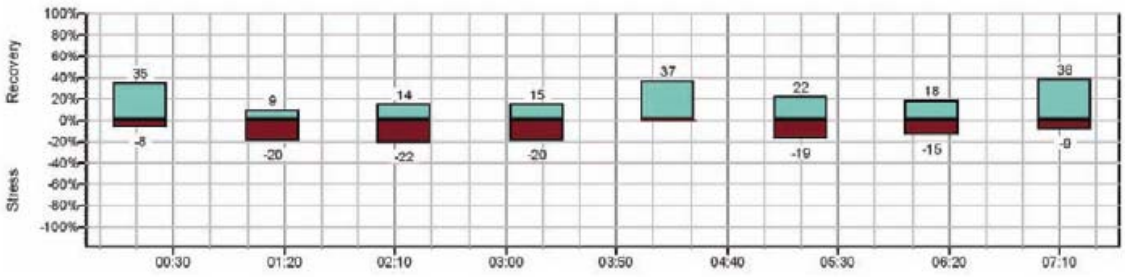


Figure 4 : stress is present during whole night



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:

- Maximize 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;
- 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 and 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).

Figure 5: shopping during the day – poor recovery

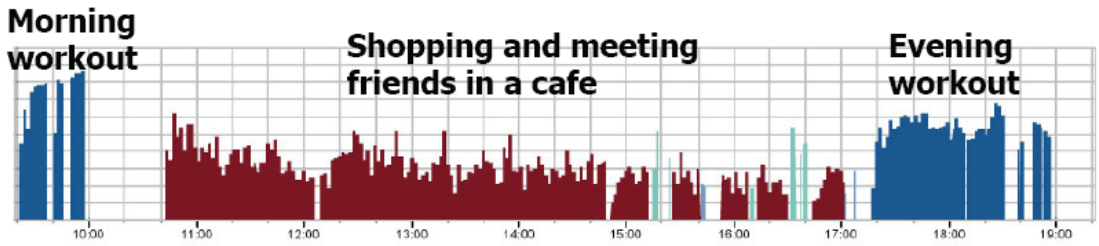
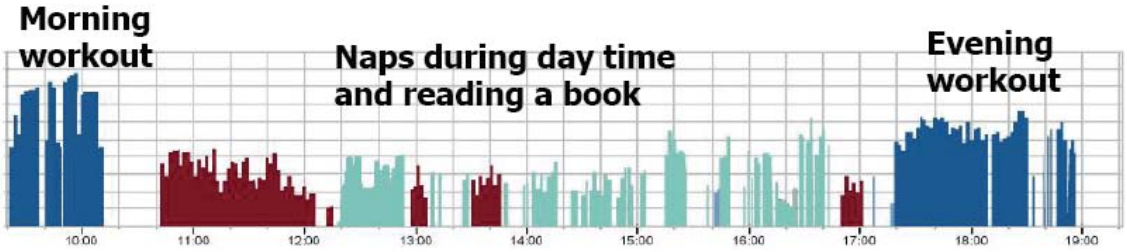


Figure 6: napping and reading during the day – good recovery



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 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 following overnight log of the recovery stress index showing very little recovery:

Figure 7: full working day stress index for James

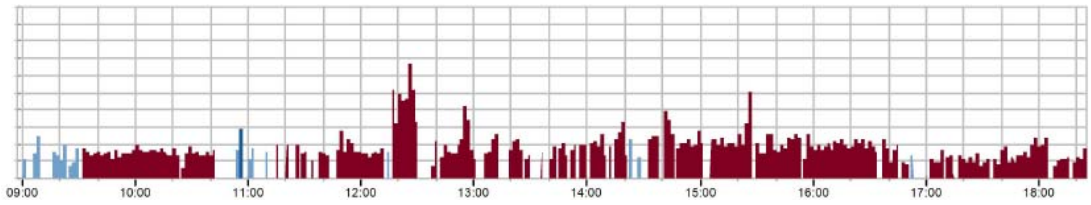
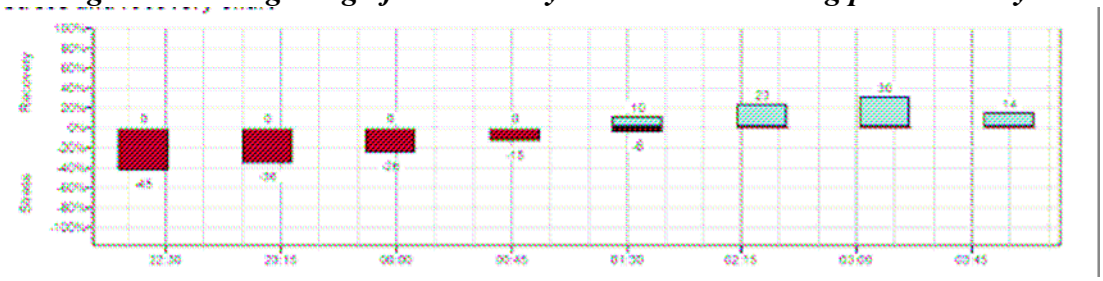
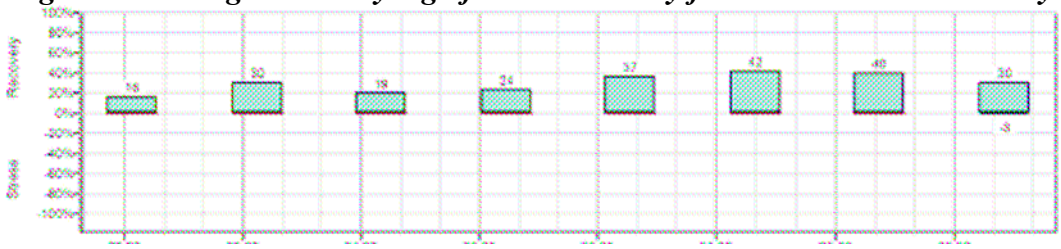


Figure 8:overnight log of the recovery stress index showing poor recovery



Now compare this with figure 9, which shows James' overnight recovery log after a week away from work, but having climbed Mount Kilimanjaro just 3 days previously! His recovery stress index scored +100, which meant he was fully recovered.

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



Conclusion

HRV is a relatively simple, but effective tool for regular checks of progress during endurance training programs. Over training 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 activites like shopping may impose more stress rather than help recovery. Taking a nap, reading a book or listening to music appear to be excellent destressors. 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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GLOSSARY

Cardiac autonomic modulation
Regulation of the heart which occurs automatically

Parasympathetic activity
Activity which slows down the heart beat