# MONITORING TO SUPPORT RECOVERY

**Recovery is a multifaceted restorative process relative to time (Kellmann et al., 2018). It can help athletes transition into a state of physical and mental readiness. Monitoring can help to understand causes of stress and fatigue, and can help to inform training and recovery strategies to minimise the risk of under-performance, illness and/or injury (Halson, 2014; Thorpe, 2021; Beato, et al., 2024).**

**Specifically, monitoring can be used to:**

**QUANTIFY EXERCISE DEMANDS**
What are the demands of training and competition?

**UNDERSTAND EXERCISE RESPONSE**
Is the athlete fatigued?

**HELP UNDERSTAND READINESS**
Is the athlete ready to exercise again?

This chapter provides a range of tools and information to help navigate the athlete monitoring process. The choice of monitoring variables and methods likely depends on the available resource (time, money, or human resource) to support the collection, processing, and analysis of data.

Table 5 highlights examples of variables that could be utilised to monitor load, stress, fatigue and/or readiness. A selection of these variables may be incorporated into a monitoring system, personalised to needs of an individual athlete or team. Some variables may be measured both objectively and subjectively. Typically, objective and subjective measures should not be compared with each other, but can be monitored and analysed in unison to provide a more comprehensive understanding of recovery (Beato, et al., 2024).

Few of these variables have strong scientific evidence supporting their use, and to date, there is no gold-standard variable to monitor load and/or fatigue (Halson, 2014). In addition, a recent review has discussed the use of these variables in monitoring readiness in female athletes (soccer players), noting the majority of research on readiness in this cohort has been carried out in the male population (Beato, et al., 2024). Such should be considered when evaluating the efficacy of different monitoring methods.

Each variable will be measured in different ways. Typically, data gained from these variables can be interpreted relative to the intra-variability of each athlete's measurements. This can help to estimate the 'minimal detectable change' for each individual. In addition, data can be interpreted relative to the minimal value that is of practical or clinical significance (MCID) (Thorpe, et al., 2017; Schneider, et al., 2018; Freese, et al., 2023).

Wearable devices (smart watches, rings, etc) often provide stress, recovery, or readiness 'scores'. These scores are estimates and often based off assumptions, making them difficult to validate. In addition, the scores often lack context (i.e. are the scores a result of physiological changes, or assumptions based on behaviour?). As such, if wearable devices are used to monitor recovery, focusing on variables that these devices measure, rather than estimated scores, may be more reliable for helping to understand the body's responses, and to help make informed decisions (Altini, 2024).

Table 6 provides a checklist that can be used to help ensure the use of relevant, feasible and sustainable measures when building a monitoring system.

In addition to this toolkit, GSSI have a number of resources that review athlete monitoring, and associated variables in detail, including GSSI SSE #135 Monitoring Fatigue and Recovery (Halson, 2014), GSSI SSE #245 Monitoring Recovery in American Football (Freese, et al., 2023) and the GSSI Sports Nutrition for Basketball resource. Separate reviews discuss monitoring of recovery in Team Sport athletes (Thorpe, et al., 2017) and Female Football (Beato, et al., 2024).

| MONITORING VARIABLE | UNITS / DESCRIPTORS |
|---|---|
| **Frequency** | Sessions per day \| Sessions per week \| Sessions per month |
| **Time** | Seconds \| Minutes \| Hours |
| **Intensity** | Absolute \| Relative |
| **Type** | Modality \| Environment |
| **Maximal Effort** | Max mean power \| Jump height |
| **Repeat Efforts** | Number of efforts \| Quality of efforts |
| **Training Volume** | Time \| Intensity |
| **Perception of Effort** | RPE \| Session RPE |
| **Heart Rate** | Heart rate \| Heart rate recovery \| Heart rate variability |
| **Perception of Fatigue and Recovery** | Questionnaires \| REST-Q \| VAS |
| **Illness** | Incidence \| Duration |
| **Injury** | Type \| Duration \| Severity (classification) |
| **Biochemical, Hormonal and Immunological Analysis** | Baseline \| Response to exercise |
| **Technique** | Movement deviations |
| **Body Composition** | Total body mass \| Fat mass \| Free-fat mass |
| **Sleep** | Quality \| Quantity \| Routine |
| **Psychology** | Stress \| Anxiety \| Motivation |
| **Sensations** | Hopeful \| Neutral \| Hopeless |

**Table 5**

Examples of variables that can be used to monitor training load, stress, fatigue and/or readiness. Adapted from Halson (2014). This list is not extensive. RPE – Rating of Perceived Exertion; REST-Q – Recovery Stress Questionnaire; VAS – Visual Analogue Scale

| MONITORING SYSTEM CONSIDERATION | YES/NO* | COMMENTS |
|---|---|---|
| **WHY IS THE MONITORING SYSTEM NEEDED?** | | |
| Is there a clear rational as to why the monitoring will be occurring? | | |
| **WHAT WILL BE MONITORED?** | | |
| Is there a clear rational as to what will be monitored? | | |
| Is the monitoring system specific to the sport in question? | | |
| Is the system flexible and adaptable for different sports and athletes (where applicable)? | | |
| Is an assessment of cognitive function included (if relevant)? | | |
| **WHEN WILL MONITORING OCCUR?** | | |
| Is there a clear rational as to when the monitoring will be occurring? | | |
| Will the system be used frequently enough to provide necessary information, without reducing compliance? | | |
| **HOW EASY IS THE MONITORING SYSTEM TO USE?** | | |
| Can measurements within the system easily be standardised to ensure reliability of data collection? | | |
| Does the practitioner have the knowledge/ experience to implement the system? | | |
| Is the system easy to use, with an intuitive design? | | |
| Will the system take minimal time for athletes to complete (where relevant?) | | |
| Can the system be utilised effectively remotely (with or without internet)? | | |
| Is the system sustainable from a human resource, time, and financial point of view? | | |
| **HOW WILL THE DATA BE INTERPRETED?** | | |
| Has the monitoring system / measurement device or method been validated? | | |
| Does the practitioner have the knowledge / experience to interpret the data collected? | | |

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|---|---|---|
| **Is there a clear rational as to how the data will be interpreted?** | | |
| **Is it possible to interpret the data with the context of data collection in mind?** | | |
| **Can the data provide both individual and group responses (where applicable)?** | | |
| **Can data be translated into simple outcomes, such as effect sizes?** | | |
| **Is the identification of a meaningful change simple and efficient?** | | |
| **Is there a simple indicator as to if an intervention is required?** | | |
| **HOW WILL FEEDBACK BE PROVIDED / RESULTS UTILISED?** | | |
| **Can results be reported efficiently?** | | |
| **Is it possible to implement change based on the data collected?** | | |
| **Is it possible to provide feedback?** | | |
| **Is there a clear rational as to how feedback will be provided/presented to coaches / athletes?** | | |
| **Can feedback be provided in a way that is easy for coaches / athletes to interpret?** | | |
| **Can feedback be presented soon after data collection?** | | |

**Table 6**

Checklist for creating a relevant and sustainable monitoring system. Adapted from Halson (2014). *Answering questions with a 'Yes' indicates that appropriate considerations in the development of a relevant and sustainable monitoring system have been accounted for. If any questions are answered with a 'No', the specific question should be reviewed and the monitoring system should be adapted appropriately, with the aim that the majority of answers, if not all, are answered with a 'Yes'.

## MONITORING METHODS

**This section contains tools and guidance to support the monitoring of variables listed in Table 5.**

### QUANTITATIVE MEASURES *(frequency, time, intensity, type, training volume)*

Quantitative measures of training load monitor controllable (training, practice, etc.) and uncontrollable (games) variables of work completed by athletes. Such work contributes to physiological and psychological fatigue. These measures are specific to each athlete, and will thus impact each athlete's levels of fatigue to different extents.

As such, any quantitative measures should be measured on an individual basis, taking into account which variables will be most suited to answer the specific question of interest. For example, 'distance covered' may be a good variable to monitor fatigue in a soccer player who plays in midfield. However, this measure may not be as useful in the monitoring of a Goalkeeper. When collecting these measurements, it is important to capture all exercise, and to be as exact as possible (Freese, et al., 2023).

Many quantitative measures of load can be collected manually (e.g. frequency, time, type) and are low-cost, reliable and accurate measurements. Other measures (e.g. intensity) might require support of technologies. Examples of these technologies include Global or Local Positioning System devices (GPS and LPS respectively), or power output measuring devices. Data collected by these devices can be compared against the literature to evaluate factors such as training intensity.

These quantitative measures can be collected on a daily basis, and compared over time to identify trends, or significant changes. For example, an increase in any of the quantitative measures may indicate an acute or chronic increase in training load, thus indicating an increased demand for recovery.  Table 7. can be used to list the quantitative measures that will be used for monitoring purposes, and to document how these measures will be used, to help build a monitoring strategy.

### PERFORMANCE MEASURES / NEUROMUSCULAR FUNCTION *(maximal effort, repeated efforts, technique)*

Measures of performance/neuromuscular function can help monitor an athlete's response to training, and their readiness to perform. The relevant measure(s) will be specific to the athlete, depending on the mode of fatigue (i.e. is fatigue caused by running, throwing, or jumping, for example). It is not in the scope of this toolkit to cover all of the available measures, given these variations. Common measures, however, include jump tests, sprint tests, and isokinetic dynamometry, that monitor changes in maximal efforts (Halson, 2014; Thorpe, et al., 2017). These measures can provide insights into factors such as strength and power gains / losses, and muscular imbalances.

In many cases, it is difficult to replicate or define maximal performance. A fatigued athlete may lack motivation to provide a maximal effort that is not for competitive purposes, whilst, maximal testing might add to existing fatigue (Halson, 2014). On the other hand, athletes may be able to maintain these measures when fatigued by altering movement patterns (Beato, et al., 2024). These factors should be considered when building tests for, and analysing results of performance/neuromuscular function.

Joint range of motion/flexibility may also be useful monitoring variables to provide insights into structural fatigue and potential injury risk (Thorpe, et al., 2017). Such assessments can be led by physiotherapists/athletic trainers.

Equipment-specific operating procedures should be used when running these tests, whilst following sport-specific protocols. In addition, methods should be consistent over time to avoid error and reliability issues. Factors such as standardising warm ups, hand placement and squat depth (where relevant), timing of assessment (pre/post-exercise, days following competition, etc.) and encouraging maximal effort, may influence the quality of results (Freese, et al., 2023). Thus, a single protocol should be established at the beginning of a competitive season and followed to reduce variability in data, and allow for better interpretation and identification of neuromuscular fatigue.

Performance/neuromuscular function measurements can be taken less frequently than quantitative measures (e.g. weekly, or monthly). These measurements can be compared over time to identify trends, or significant changes. This information can provide insights into athletes' levels of fatigue / recovery status, thus informing readiness and/or potential requirements to adapt recovery strategies. Table 7. can be used to list the performance / neuromuscular measures that will be used for monitoring purposes, and to document how these measures will be used, to help build a monitoring strategy.

| MEASURE | HOW WILL THIS MEASURE BE USED TO MONITOR TRAINING LOAD / RECOVERY? |
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**Table 7**

Tool to list quantitative, performance and neuromuscular monitoring measures, specific to the sport/athlete. Room is provided to document how each measure will be used to help monitor training load / recovery.

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## PERCEPTION OF EFFORT

### RATING OF PERCEIVED EXERTION (RPE)

Perception of effort is a simple, low cost monitoring method. It allows athletes to define how easy or difficult they find an exercise session by proving a rating of perceived exertion. RPE can be monitored over time and can help to identify sessions with a high RPE, or sessions whereby the RPE is higher than typical for a similar session (possibly suggesting an increase in fatigue).

Figures 5 and 6 provide two RPE scales that can be shared with athletes to monitor perception of effort. Figure 5 provides the original Borg RPE scale, with the scale ranging from 6 to 20. This scale was designed to suggest that a rating of 6 would correlate with a heart rate of 60 beats per minute (bpm), and a rating of 20 would correlate with a heart rate of 200 bpm for 30 – 50 year old individuals. This system was designed to help practitioners interpret the ratings provided (Borg, 1982; 1998). However, any given rating will not always mean that the athlete has the corresponding heart rate. Figure 6 provides an adapted version of the Borg scale, known as the 'Category Ratio' scale. This has a scale from 0 to 10, simplifying the scale for the end user (Borg, 1982; 1998).

Each RPE chart should be presented to athletes with appropriate text/prompts, which can be adapted depending on the feedback that is required from the athlete. This prompt will help to inform the athlete as to the context in which they should report their results. The athlete should then indicate their RPE, either verbally, or by pointing to the chart. Examples of potential prompts are listed below:

| | | |
|---|---|---|
| How hard does/did your session feel? | How hard does/did your session feel compared to yesterday? | How hard does/did your session feel compared to the last time you completed a similar session? |

Both scales should also be anchored by relevant verbal expressions, aiding athletes' ratings (i.e. 'Easy' to 'Hard'). The expressions can be adapted depending on the insights of interest. For example, depending on the prompt used, the expression 'Easy' could be changed to 'Weak', and 'Hard' could be changed to 'Heavy'. Figures 5 and 6 have space to add the required prompt above each RPE scale, which in turn can be used with athletes. The scales should not be modified with multiple colours or images as these may influence responses.

### SESSION RPE (sRPE)

Session RPE is one overall RPE for the totality of an exercise session, and can also be used to monitor athletes. To enable athletes to rate the global intensity of an entire session, the Category Ratio scale (Figure 6) should be presented to athletes post-exercise for ratings to be collected. Requesting the rating 30 minutes post-exercise (if logistical) can be helpful to reduce the likelihood of the score being skewed as a result of particularly difficult or easy segments at the end of the exercise session (Foster, et al., 2001). In addition, the presence of other individuals (e.g. athletes and coaches) whilst athletes are rating a session can impact sRPE. Consequently, the environment in which athletes rate the session (i.e. if an athlete is alone, or with others), should be standardised for each rating to minimise the risk of error and ensure reliability of data. Such data should be analysed with the context of collection in mind (Minett, et al., 2022).

sRPE can subsequently be multiplied by the duration of exercise in minutes to provide an overall score to quantify training load in Arbitrary Units (Figure 4).

| sRPE | × | Duration of Exercise | = | Training Load |
|---|---|---|---|---|
| ____________ | | ____________ minutes | | ____________ A.U. |

RPE and subsequent estimates of training load can be used to monitor athletes, and analyse subsequent recovery needs in a number of ways:

- If RPE are at the higher end of the scale, there may be an increased demand for recovery
- If RPE/training loads are higher than usual for an athlete compared to the a similar bout of exercise, this might indicate that an athlete is not sufficiently recovered. (Note that there may be additional factors contributing here, for example if the athletes are under fuelled or hypohydrated)

Monitoring these measures can provide insights into an athlete's perceived recovery status, thus informing readiness and/or potential requirements to adapt recovery strategies.

**Figure 4** ▲

Calculation for estimating training load, using Session RPE. A.U. = Arbitrary Units. (Foster, 1998; McLaren, et al., 2018).

## RATING OF PERCEIVED EXERTION (RPE) SCALE

PROMPT:

| SCORE | LEVEL OF EXERTION |
|---|---|
| 6 | No exertion at all |
| 7 | |
| 8 | Extremely easy |
| 9 | Very easy |
| 10 | |
| 11 | Easy |
| 12 | |
| 13 | Somewhat hard |
| 14 | |
| 15 | Hard |
| 16 | |
| 17 | Very hard |
| 18 | |
| 19 | Extremely hard |
| 20 | Maximal exertion |

**Figure 5**

Borg Rating of Perceived Exertion Scale.
Adapted from Borg (1982) and Borg (1998).

## RATING OF PERCEIVED EXERTION (RPE) SCALE

PROMPT:

| SCORE | | LEVEL OF EXERTION |
|---|---|---|
| 0 | ○ | No exertion at all |
| 1 | ○ | Very, very easy |
| 2 | ○ | Easy |
| 3 | ○ | Moderate |
| 4 | ○ | Somewhat hard |
| 5 | ○ | Hard |
| 6 | ○ | |
| 7 | ○ | Very hard |
| 8 | ○ | |
| 9 | ○ | |
| 10 | ○ | Maximal |

**Figure 6**

Category Ratio Rating of Perceived Exertion Scale. Adapted from Borg (1982) and Foster, et al., (2001).

## HEART RATE (HR)

Indicators of Autonomic Nervous System (ANS) function can contribute to the understanding of an athlete's overall fatigue status. These indicators include varying measures of heart rate (HR), which are non-invasive, and can be time-efficient and cost-effective (Schneider, et al., 2018).

### MEASURING HEART RATE

There are a multitude of methods to measure HR. Electrocardiography is the gold-standard, however this method is not practical for use during exercise. Electrode-based HR monitors are also accurate in the monitoring of HR, and may be more practical in the sporting environment. Wrist-worn fitness and heart rate monitors that use optical technology, on the other hand, are less accurate; the accuracy of wrist-worn devices are often best at rest, but diminished with exercise (Wang, et al., 2017).

When HR variables are measured, it is advisable to control for factors such as hydration, environment (noise, light, temperature) and medication, amongst others. These factors can all impact HR, independent of exercise intensity (Bagger, et al., 2003; Schneider, et al., 2018). In addition, data should ideally be collected using the same device over time. The context of data collection should also be considered when reviewing data, given factors like emotional excitability related to practice or competition may elevate HR independent to training load variables (Schneider, et al., 2018; Freese, et al., 2023).

### RESTING HEART RATE (HRrest)

Some methods that use HR to monitor athletes require an understanding of HRrest. HRrest can be recorded for 5-10 minutes upon waking in the morning, whilst in the supine, or seated positions (Buchheit, 2014). The average HR over this time period is the HRrest. To get a baseline measure, it may be useful to measure HRrest during, or before the pre-season, during a lighter period of training.

### EXERCISE HEART RATE (HRex)

HRex is an athlete's submaximal HR during the last 30-60 seconds of exercise, and is one of the easiest HR measures to collect. Comparing HRex to an athlete's pre-determined maximum HR (HRmax) to provide a percentage of HRmax, can help to monitor exercise intensity (Borresen & Lambert, 2008; Buchheit, 2014; Halson, 2014). Working at a higher percentage of HRmax may indicate higher exercise demands, and thus an increased demand for recovery.

In intermittent sports, HR will vary throughout exercise. Training Impulse (TRIMP) models take this variation into account. TRIMP is measured in Arbitrary Units, and is an assessment of the amount of exercise (physical effort) undertaken during an individual session, thus giving an insight into training load. Specifically, TRIMP is measured using duration of training (minutes) and different measures of HR (average HRex, HRmax and resting HR) (Banister & Calvert, 1980; Morton, et al., 1985). It is important to have an understanding of baseline HR profiles (including annual measures of HRmax, rather than using predictions (i.e. 220 – age)) before calculating TRIMP (Freese, et al., 2023). A variety of calculations are proposed for TRIMP models, hence one single calculation is not shared here.

On the other hand, HR may be measured during standardized exercise protocols (i.e. exercise sessions that can be repeated in identical conditions, such as intensity, duration and timing in the day). Average HRex can be compared to athletes' 'norm' for a given protocol, to identify meaningful changes that may indicate fatigue (i.e. HRex higher than normal for the same protocol). However, such protocols may be difficult to fit into already busy competitive schedules and may further contribute to fatigue. In addition, HRex does not always fluctuate despite changes in training load, and factors such as motivation may result in higher performance outcomes, independent of HRex (Schneider, et al., 2018). Accordingly, such data should be interpreted with caution, and if possible, in combination with additional measures of fatigue (Thorpe, et al., 2017).

### HEART RATE RECOVERY (HRR)

Heart Rate Recovery provides insights into the ANS shift from sympathetic to parasympathetic activity. To monitor HRR, HR is measured during the last 15 seconds of exercise, and at 1 minute post-exercise. HRR is calculated as the percentage change between HRex, and HR recorded post-exercise (Figure 7). This highlights the rate at which HR declines within the cessation of exercise (Lamberts, et al., 2010;

Daanen, et al., 2012). A decrease in HRR over time (compared to previous measurements) may suggest an imbalance between training load and recovery (Lamberts, et al., 2010). This data could be used to understand an athlete's recovery status and subsequently help to inform recovery strategies. However, it is unclear as to how useful this measure is, especially during intensified periods of training (Daanen, et al., 2012; Bellenger, et al., 2016; Thorpe, et al., 2017).

$$\left[\frac{\text{HRex } \_\_\_\_\_ \text{ bpm} - \text{HR post-exercise } \_\_\_\_\_ \text{ bpm}}{\text{HRex } \_\_\_\_\_ \text{ bpm}}\right] \times 100 = \text{HRR } \_\_\_\_\_ \%$$

Figure 7

A calculation of Heart Rate Recovery.

### HEART RATE VARIABILITY (HRV)

Heart Rate Variability assesses variation in time between consecutive heart beats and can give an insight into the activity of the ANS. In general, an increase in HRV may indicate an increased move towards more parasympathetic activity and a decrease in HRV may indicate an increased move towards more sympathetic activity (Altini & Plews, 2021). Together, monitoring HRV may provide an insight into an individual's response to stress.

Electrocardiography (ECG), is the gold-standard method to monitor HRV, but is expensive and time consuming. Alternative methods include the use of HR chest straps, and smartphone photoplethysmography (PPG) (Plews, et al., 2017). Measurements, using any of the aforementioned methods, can be taken each morning whilst resting, before consuming foods and beverages to provide a rolling (weekly) average of HRV. This is the most accurate method to measure HRV, away from stressors (Altini, 2024). A rolling average can better highlight significant changes, compared to single, isolated values with high day-to-day variability (Plews, et al., 2013). Data can then be analysed using smartphone applications, or specialist software (Plews, et al., 2017). Information on specific indices that are measured can be found elsewhere (Haddad, et al., 2011; Plews, et al., 2013).

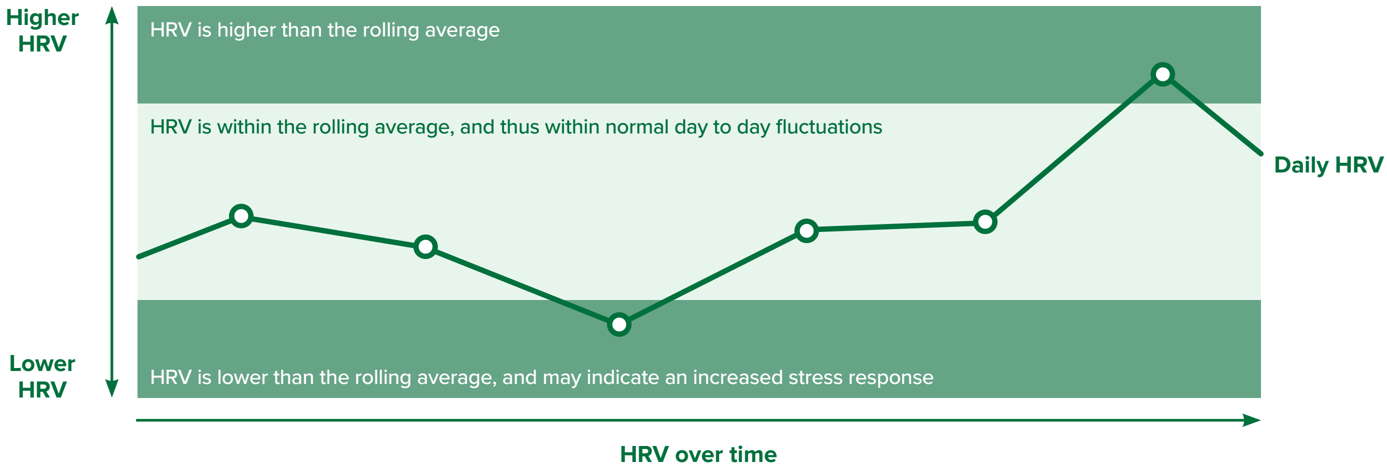
Overtime, increases in an individual's average resting HRV may be a result of increased fitness, as a result of consistent training (Lundstrom, et al., 2023). On the other hand, acute decreases in daily HRV, compared to the rolling average, may indicate an increased stress response (Altini & Plews, 2021). Figure 8 highlights how changes in daily HRV could be interpreted. Due to individual variations in HRV, it is important that changes in HRV are compared at an individual level (Beato, et al., 2024).

An increased stress response could be a result of a heavy training load (Thorpe, et al., 2017), and may result in impaired performance (Lundstrom, et al., 2023). However, changes in HRV of all magnitudes (increases, decreases and no change) have been reported in athletes who have improved fitness levels over time, and in those with intensified training periods. In addition, other non-exercise factors may influence changes in HRV (Halson, 2014; Bellenger, et al., 2016; Thorpe, et al., 2017). Consequently, more research is required to evaluate how efficacious HRV monitoring is in evaluating changes in stress response. In the meantime, HRV data should be interpreted with caution.

Together, indicators of Autonomic Nervous System (ANS) function, in this case HR, HRR and HRV, can be used to monitor athlete stress, fatigue and recovery status to inform readiness and/or potential requirements to adapt recovery strategies. In addition, measures of HR variability may be used as a measure to investigate the effectiveness of different recovery strategies.

**Figure 8**

Example of how changes in an individual's daily HRV could be interpreted when monitoring athletes.




## PERCEPTION OF FATIGUE AND RECOVERY

Subjective, perceptual scales can be used to help understand an athlete's perception of fatigue and recovery. Example subjective and perceptual monitoring tools are discussed below. An understanding of perception of fatigue and recovery can also be gained through regular conversations with athletes. However, this might not be feasible/efficient on a daily basis, given the demands of the sports performance team, and number of athletes with teams.

### QUESTIONNAIRES

Questionnaires can provide an insight into an athlete's level of stress, fatigue and response to recovery (Halson, 2014; Thorpe, et al., 2017; Kellman, et al., 2018; Beato, et al., 2024). These insights can be used to help develop or adapt athlete/team specific recovery strategies.

Table 8 provides examples of questionnaires, and highlights their potential uses. If questionnaires are utilised, the frequency at which they are shared, and the length of the questionnaire should be considered to minimise questionnaire 'fatigue' and thus maximise compliance (Halson, 2014). In addition, it may be helpful to review responses to the questions in combination with additional monitoring variables (Beato, et al., 2024). In order to allow for reliable comparisons in data, the questionnaires may be asked at the same time each day, and the context of that timepoint should be considered when evaluating results.

| PERCEPTION OF FATIGUE AND RECOVERY RESOURCE | USE |
|---|---|
| **Profile of Mood States (POMS)** | Measures various mood states, and can provide a global measure of mood. Disturbances in mood state may indicate an increase in training load (McNair, et al., 1971; Morgan, et al., 1987) |
| **Recovery-Stress Questionnaire for Athletes (RESTQ-Sport)** | Measures frequency of stress symptoms and recovery-related activities to provide an insight into athletes' recovery-stress state ( (Kellmann & Kallus, 2001; Kallus & Kellmann, 2016) |
| **Daily Analysis of Life Demands for Athletes (DALDA)** | Evaluates whether an athlete is stressed and if so, what the factors are leading to the stressed condition (Rushall, 1990) |
| **Total Quality Recovery Scale (TQR)** | Measures psychophysiological recovery (Kenttä & Hassmén, 1998) |
| **Acute Recovery and Stress Scale (ARSS) and Short Recovery and Stress Scale (SRSS)** | Monitors athletes' current recovery-stress states and may be used for longitudinal analysis (Nässi, et al., 2017; Kellmann, et al., 2018) |
| **Rating of Fatigue Scale** | Measures perceptual ratings of fatigue in various settings (Micklewright, et al., 2017) |
| **Hooper Index** | Assesses subjective readiness such as muscle soreness, fatigue, sleep, sleep quality and mental feeling to perform (Hooper & Mackinnon, 1995; Beato, et al., 2024) |

**Table 8**

Examples of athlete monitoring questionnaires.

### VISUAL ANALOGUE SCALE (VAS)

Visual analogue scales are a simple and inexpensive method to analyse perceived fatigue. VAS can provide a quick method of analysis, and thus could be used on a daily basis. VAS may be presented to athletes at the start of each day, before training. This allows daily schedules and recovery strategies to be adapted accordingly, based on athlete's perceived fatigue compared to their average ratings.

Figure 9 provides an example of a VAS that could be incorporated into a daily monitoring system. Each VAS should be presented to athletes with appropriate text (prompt), informing them as to the context in which they should report their results. For example 'How physically fatigued are you feeling'. A VAS should also utilise anchors at the start and end of the scale. These prompts and anchors can be edited depending on the required data. For example, in addition to fatigue, athletes could be asked about their level of pain, or their mood (Beato, et al., 2024). A digitalised VAS could utilise a sliding scale, whereby athletes can slide a marker to indicate their perceived fatigue. Each scale should be 100mm in length, to allow for comparisons (e.g. a score at 10mm would be equivalent to 1 out of 10). Figure 10 provides an empty template that can be adapted dependent on the insights of interest.

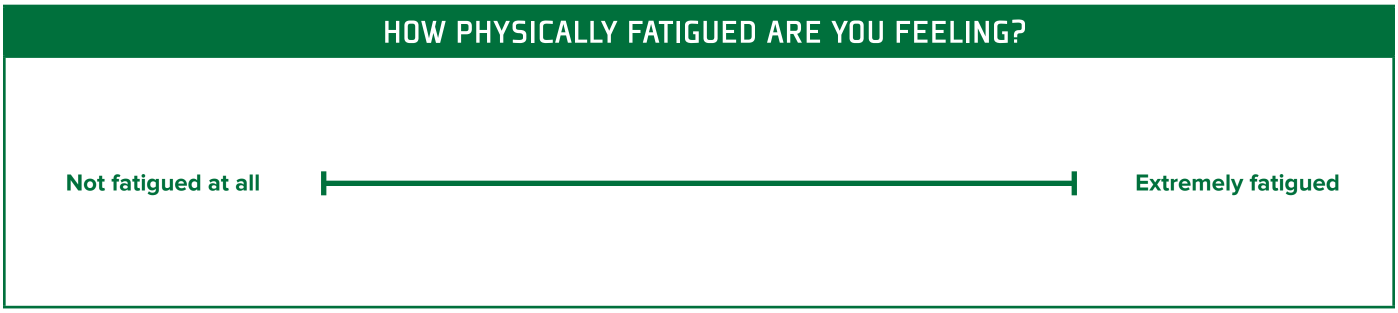



**Figure 9**

Example Visual Analogue Scale to help monitor physical fatigue.

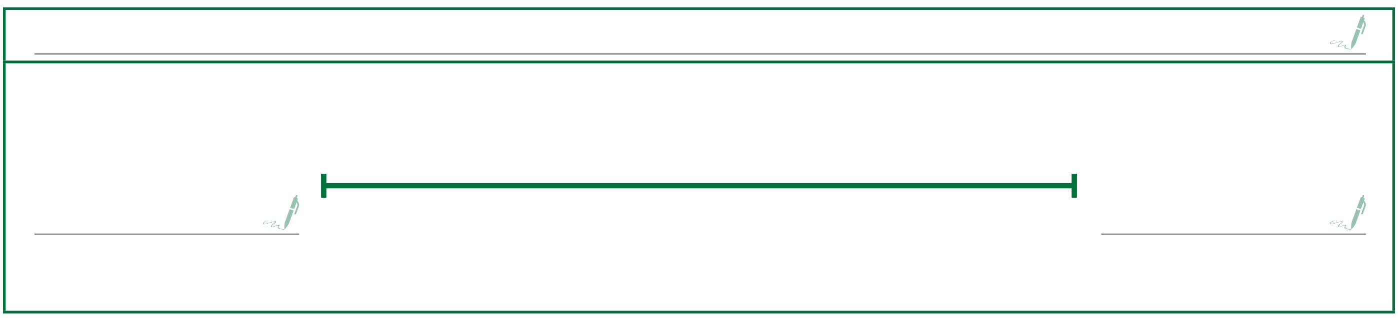


**Figure 10**

Template Visual Analogue Scale. To be edited and utilised dependent on the insights of interest.

## ILLNESS AND INJURY

Fatigue and inadequate recovery can increase risk of illness and injury. Tracking illness and injury over time can help identify significant changes and trends in the incidence, type, severity and duration of illness and injury in individual athletes. These changes may be the result of higher exercise demands and/or periods of inadequate recovery. Mapping this data across the competitive season allows the for comparison against quantitative monitoring measures (frequency, time, intensity, type and volume of training) and could help identify potential training patterns whereby athletes may be at higher risk of illness and/or injury. In turn, this information can be used to help identify, or modify relevant recovery strategies to help mitigate this risk in the future.

## BIOCHEMICAL, HORMONAL AND IMMUNOLOGICAL ASSESSMENTS

### BLOOD BIOMARKERS

Monitoring blood biomarkers, whilst invasive, can help gain an insight into an athlete's response to training, and in turn, help adjust recovery strategies as required. However, no definitive biomarker for recovery has been identified to date (Thorpe, et al., 2017). Nor are there specific ranges of each biomarker that might indicate fatigue or recovery. Instead, biomarkers of interest should be measured relatively frequently, by trained professionals (Phlebotomists). These biomarkers can then be compared against athletes' average, or 'norm' (Pedlar, et al., 2019). Table 9 provides a list of blood biomarkers that may be used to aid the monitoring of recovery.

| PHYSIOLOGICAL OUTCOME | BLOOD BIOMARKER | WHAT MIGHT A MEANINGFUL CHANGE IN THE BIOMARKER INDICATE? |
|---|---|---|
| OXIDATIVE STRESS | **Lipid and protein hydroperoxides** | Increase may indicated oxidative stress |
| | **Isoprostanes** | |
| | **Protein carbonyls** | |
| INFLAMMATION | **IL-6** | Increase may indicate inflammation |
| | **C-reactive protein** | |
| MUSCLE DAMAGE | **Creatine kinase** | Increase may indicate muscle damage |
| STRESS | **Testosterone** | Chronic decrease may indicate that training volume and intensity exceeds the body's tolerance |
| | **Cortisol** | Chronic increase may indicate overreaching and/or impaired capacity for recovery and may impact sleep, mood and performance |
| | **Testosterone:Cortisol (T:C) ratio** | A lower T:C ratio may indicate overreaching and poor recovery, which may impact performance |

### SALIVARY BIOMARKERS

Monitoring salivary biomarkers is a non-invasive, quick (30 – 90 seconds) and inexpensive alternative to blood and does not require the use of a qualified professional to collect or analyse samples. In addition, fewer supplies are required when collecting salivary samples versus blood, and saliva collection may result in less stress for athletes than the collection of blood. Due to its non-invasive nature, saliva collection may be performed more frequently which can help gain an insight into an athlete's most current response to training, and in turn, help them adjust recovery strategies as required in real time. Table 10 provides a list of salivary biomarkers that may be used to aid the monitoring of recovery.

**Table 9**

Potential blood biomarkers to assess tolerance to training and inform recovery needs of athletes (Alzaid, et al., 2015; Lee, et al., 2017; Thorpe, et al., 2017; Pedlar, et al., 2019; Beato, et al., 2024).

| PHYSIOLOGICAL OUTCOME | SALIVARY BIOMARKER | WHAT MIGHT A MEANINGFUL CHANGE IN THE BIOMARKER INDICATE? |
|---|---|---|
| IMMUNITY | **Salivary Immunoglobulin A (SIgA)** | Decrease may indicate risk of developing upper respiratory tract symptoms<br><br>Chronic decrease may indicate overreaching |
| STRESS | **Cortisol** | Increase may indicate overreaching and/or impaired capacity for recovery. Increase may also impact sleep, mood and performance |
| | **Testosterone:Cortisol (T:C) ratio** | A lower T:C ratio may indicate overreaching and poor recovery, which may impact performance |

## SALIVA COLLECTION

Food, drink and teeth brushing should be avoided within one hour of saliva collection, to limit contamination. Rinsing athletes' mouths with distilled or deionized water 10-15 minutes prior to collection can also help limit contamination (Yamuna & Muthu, 2017). Rinsing the mouth less than 10 minutes prior to collection may dilute the saliva sample, thus is not recommended. Samples should be collected at the same time of day using the same cadence (eg. 1 day post-competition, 2-day post-competition, etc) each time they are collected (Papacosta & Nassis, 2011). There are different methods to collect and analyse saliva. Collection methods including the passive drool and swab methods, as well as the use of Point of Care technologies, are discussed below.

### PASSIVE DROOL METHOD

The collection of passive drool is the gold standard method for collecting salivary samples, and allows for the evaluation of volume of saliva collected and salivary flow rate. An individuals passive drool can be collected in sterile vials by allowing saliva to pool in the mouth, before tiling the head forward, with the mouth open. Sample collection may take around 3 to 10 minutes, depending on volume required for analysis, and salivary flow rate.

### SWAB METHOD

An alternative method to the collection of passive drool is the use of an oral, sterile cotton swab. This method may be useful when athletes have trouble producing saliva. It is recommended that the swab is placed directly below, or on the tip of the tongue, to avoid stimulation from saliva glands. The swab should be held in one place for one to two minutes or until the swab itself indicates a sufficient amount of saliva has been collected.

### SWAB METHOD: POINT OF CARE TECHNOLOGY

Point-of-contact salivary analysers can also be used to collect samples. Again, a swab is used to collect a saliva sample, however in this case athletes are not required to keep the swab in the mouth for the entire one to two minutes. Equipment specific standard operating procedures should be followed.

### FLOW RATE

In specific cases, including the analysis for SIgA, correcting for salivary flow rate is necessary. Salivary flow rate can be affected by several factors, such as stress and exercise intensity (Aristidis, et al., 2013). Figure 11. can be used to calculate flow rate for SIgA when the passive drool method is used. For this, the quantity and duration of saliva collection must be collected to provide a salivary flow rate. For the passive drool method, simply timing passive drool collection, and measuring quantity of saliva collected is sufficient. If an absorbent device is used, weigh the swab and storage tube together before and after collection to calculate for saliva volume. Also record the

**Table 10** ▲

Potential salivary biomarkers to assess tolerance to training and inform recovery needs of athletes (Papacosta & Nassis, 2011; Lee, et al., 2017; Lindsay & Costello, 2017; Keaney, et al., 2018).

length of time the swab is in the mouth, so that salivary flow rate can be calculated. Once the measured concentration of SIgA is obtained (see ‘Saliva Analysis’ below), flow rate for SIgA can be calculated as illustrated below.

| **Concentration of SIgA** | × | **Salivary Flow Rate** | = | **SIgA Flow Rate** |
|---|---|---|---|---|
| ________ µg/mL | | ________ mL/min | | ________ µg/min |

## SALIVA ANALYSIS

Once samples have been collected, samples can be analysed via enzyme-linked immunosorbent assays (ELISA) or magnetic beat-based assays (MAGPIX), however both may be costly and time consuming. Point-of-care systems, on the other hand, provide quick and efficient analysis (Dunbar, et al., 2015). Standard operating procedures specific to the equipment used should be followed.

## INTERPRETATION OF BLOOD AND SALIVA BIOMARKERS

As data is collected over time, a reference range (an athlete’s ‘norm’), can be generated. This range can be adapted over time as more results are collected. In addition, baseline measurements should be collected. 2 – 3 consecutive days of measurements during pre-season can help provide an average of the biomarkers in a rested state. As a result, critical difference thresholds (CDT) can be calculated for each biomarker, individual to each athlete. CDTs help to detect meaningful changes outside of an athlete’s norm. Depending on the direction and magnitude of change, a change outside of an athlete’s norm may indicate an increased risk of impaired performance and recovery and/or a decreased capacity to adapt (Pedlar, et al., 2019). Monitoring acute and chronic changes in blood and salivary biomarkers can therefore help monitor recovery status, inform readiness, and adapt recovery strategies where relevant. The analysis of both bloods and saliva could be used in combination with additional monitoring methods.

In addition to chronic monitoring, saliva could be used to help monitor over shorter periods of time, such as a travel occasion. Saliva samples could be taken before, during, and post travel, to see how athletes copes with travel. This acute assessment could help inform future recovery strategies. Blood analysis can also be used to help understand an athlete’s nutrition status. An inadequate status of certain nutrients may impair recovery, or result in feelings of fatigue (page 51).

A list of blood and salivary biomarkers have been provided previously (Tables 9 and 10 respectively). These biomarkers can be used to assess tolerance to training and inform recovery needs. It is not the scope of this toolkit to analyse the efficacy of each biomarker listed. Instead, Table 11. can be utilised as a checklist to assess the suitability of each biomarker. Once one (or several) biomarkers have been identified, Table 12. can be used to help ensure successful biomarker profiling.

▲ **Figure 11**

**Calculation of SIgA flow rate using the passive drool method (Salimetrics, 2024)**

**BIOMARKER OF INTEREST:** ______

| CONSIDERATION FOR BIOMARKER SUITABILITY | | YES/NO* | COMMENTS |
|---|---|---|---|
| **Evidence** | Has prior research provided a satisfactory evidence base for the use of this biomarker (clinically, in public health or in sport), and for the specific target population and sex? | | |
| **Application** | Will the biomarker provide actionable data or serve as a useful positive or negative outcome indicator? | | |
| **Validity** | Has the biomarker been demonstrated to be valid? | | |
| | If this is a new technique, does it agree with the established 'gold standard' technique? | | |
| **Variability (analytical and biological)** | Has the analytical and biological variability of the biomarker been reported? | | |
| | Is the variability of this measurement technique acceptable? | | |
| **Collection and analysis** | Is the collection procedure and analysis time fast enough to be useful? | | |
| | Is the amount of sample required appropriate (i.e. minimal)? | | |
| **Sample treatment and transportation** | Can the analysis take place *in situ* or does the sample have to be stored in a specific way and/or transported to a laboratory? | | |
| **Diurnal variation** | Is it possible to account for the potential influence of time of day, exercise, sleep and fasting status on the biomarker? | | |
| **Cost** | Is the full cost of the biomarker data justified? | | |
| **Covariates** | Is it possible to account for additional covariates that may influence the biomarker? e.g. environmental impact such as warm weather camp, altitude, travel stress and jet lag | | |

**Table 11**

Checklist of considerations for assessing biomarker suitability in sport. Adapted from Pedlar, et al. (2019).
*Answering questions with a 'Yes' indicates that appropriate considerations in the choice of biomarker have been accounted for. If any questions are answered with a 'No', the specific question should be reviewed and the choice of biomarker should be reconsidered, with the aim that the majority of answers, if not all, are answered with a 'Yes'.

| CONSIDERATION FOR SUCCESSFUL BIOMARKER PROFILING | YES/NO* | COMMENTS |
|---|---|---|
| **Have you assessed and identified the need for analysis with relevant members of the Sports Performance team, including the Team Doctor?** | | |
| **Have you identified a suitable biomarker? (See Table 11)** | | |
| **Have you set an appropriate frequency for testing? (Consider if the biomarker provides a 'snapshot in time' or can provide long-term insights)** | | |
| **Do you have sufficient financial resources to cover costs of collection, analysis, interpretation and feedback?** | | |
| **Is contextual information available to be used in interpretation?** | | |
| **Have you reviewed pre-analytic considerations / guidelines?**<br>**For Bloods: See Pedlar, et al., 2019**<br>**For Saliva: See pages 26 - 27** | | |
| **Are you implementing statistical best practice in data visualisation, modelling and translation?** | | |
| **Is there the availability of expertise to interpret biomarkers?** | | |
| **Is there athlete and/or coach 'buy-in'?** | | |
| **Is there an appropriate/effective feedback mechanisms in place?** | | |

▲ **Table 12**

Key factors for success of biomarker profiling in sport. Adapted from Pedlar, et al. (2019). *Answering questions with a 'Yes' indicates that appropriate pre-sampling considerations have been accounted for. If any questions are answered with a 'No', the specific question should be reviewed and reconsidered, with the aim that the majority of answers, if not all, are answered with a 'Yes'.

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## BODY COMPOSITION

Monitoring changes in body composition over time can provide insights into an athlete's training load and/or nutrition habits. Methods to monitor body composition have been discussed elsewhere (GSSI Sports Nutrition Toolkit).

Acute changes in body composition are normal, and may be a result of factors including hydration status. Chronic changes, however, for example a continued reduction in body mass, fat free mass and/or fat mass over time, likely indicate an athlete's energy intake is inadequate to meet the demands of the sport. This in turn may impact both performance and recovery.

Changes in body composition may indeed be purposeful and expected, for example, the athlete's nutritionist / dietitian may have developed a strategy to modify body composition. However, there may be cause for concern when these changes are unexpected. Figure 12 highlights potential explanations for reduced body mass, fat free mass, and/or fat mass over time.

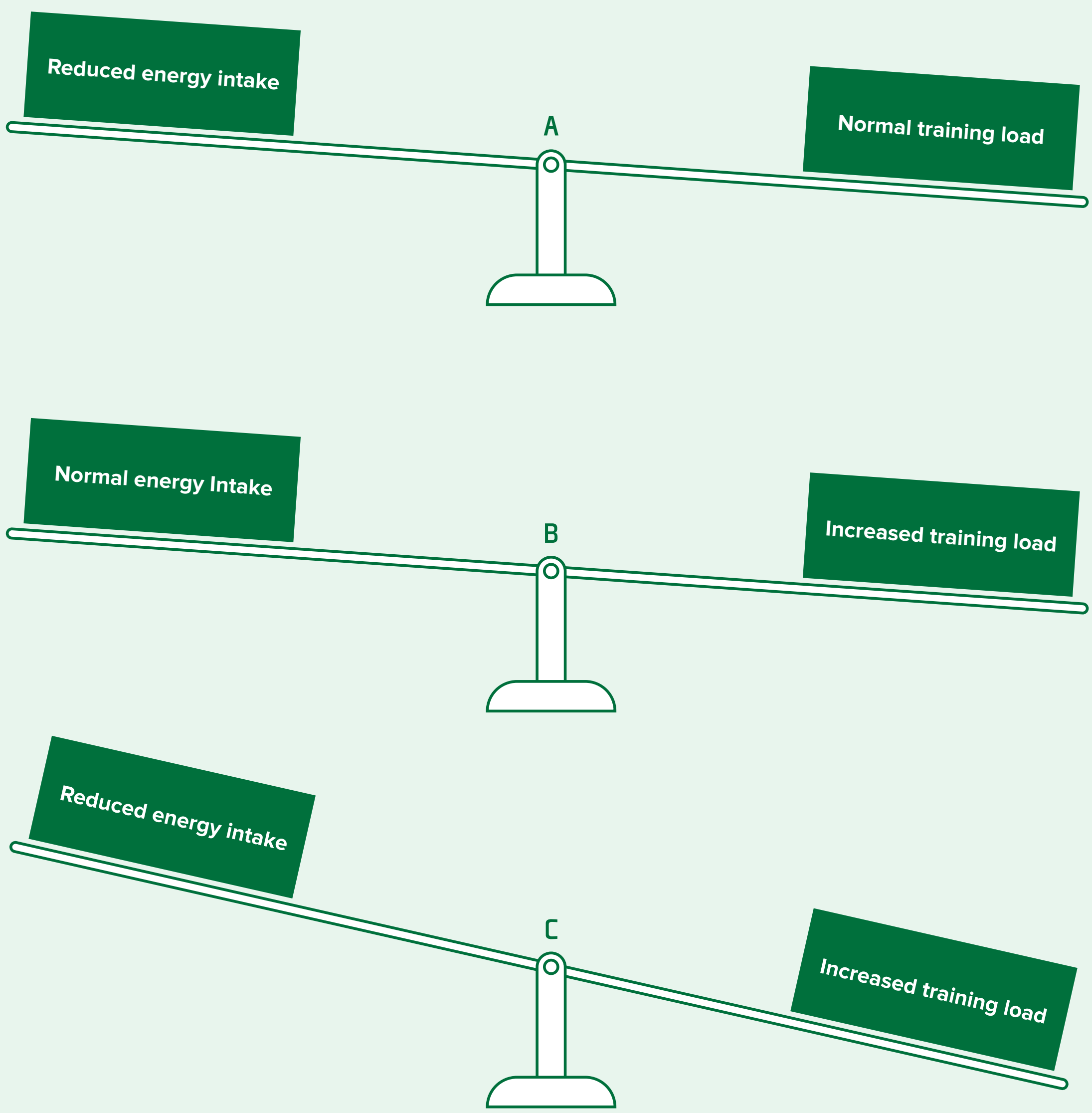



**Figure 12**

A, B and C: Potential causes for reductions in body mass, fat free mass and/or fat mass, as a result of energy intake being insufficient to meet the demands of training

Should energy intake continue to fail to match energy expenditure over a sustained period of time, the body may enter a state of Low Energy Availability (LEA). Here, the body may begin to save energy by shutting off physiological processes that are important for health (Logue, et al., 2020). LEA has a number of different signs and risk factors, some of which are listed in Table 13, though an athlete does not need to show all of these symptoms to be in LEA. It is important to understand these signs and risk factors in order to help identify athletes who may be at risk.

| POTENTIAL SIGNS AND RISK FACTORS OF LOW ENERGY AVAILABILITY | | |
|---|---|---|
| Chronic dietary restriction and/or extreme dieting | Menstrual irregularities or complete loss of menstrual cycle | Perfectionist tendencies |
| Continual and constant drive for thinness | 2+ career stress fractures | Frequent injuries |
| Significant changes in body mass or composition in short time periods | Low bone mineral density | Over training |
| Training inconsistencies and/or constant fatigue | Regular illnesses/signs of compromised immunity | Poor recovery between training sessions |
| Issues with concentrating | Reduced libido | Low iron levels |
| Reduced resting metabolic rate | Decreased cardiovascular function | Osteoporosis |

Identification of meaningful changes in body composition over time, or signs or risk factors of LEA, warrants further investigation. Both exercise demands and nutrition should be reviewed in unison. As a result, these insights could be used to adapt training, nutrition, and/or recovery strategies accordingly.

See pages 12 - 37 to support the monitoring of exercise demands. See pages 41 - 52 for more information on nutrition for recovery.

See the GSSI Sports Nutrition Toolkit for guidance and tools to help calculate an athlete's energy requirements, carry out a dietary analysis, and to support athlete consultations and goal-setting.

## SLEEP

Monitoring sleep quantity and quality can be useful for the early detection of inadequate sleep. This allows for intervention to be implemented prior to the development of significant performance, recovery and health decrements (Halson, 2014). Common terms used in the monitoring of sleep are highlighted in Table 14, alongside explanations of each term.

**Table 13**

Potential signs and risk factors of low energy availability in athletes.

| SLEEP TERM | DEFINITION / EXPLANATION |
|---|---|
| **Sleep Quantity** | The total amount of time spent sleeping. This differs from the total amount of time spent in bed and takes into account sleep latency, sleep waking and wakefulness. |
| **Sleep Latency** | The total amount of time it takes an individual to fall asleep. |
| **Sleep Waking** | A measure of how often an individual wakes up during the night. |
| **Wakefulness** | A measure of how many minutes an individual spends awake during the night after they first go to sleep. |
| **Sleep Quality** | A measure/estimate of how well an individual sleeps (i.e. whether sleep is restful and restorative). |
| **Sleep Efficiency** | The percentage of time an individual spends actually sleeping compared to the time spent in bed. |
| **Sleep Satisfaction** | Subjective judgements of how an individual feels about the sleep they are getting. |
| **Sleep Inertia** | Grogginess upon waking. |

To date, there are no accepted or standardised procedures for monitoring sleep in athletes (Halson, 2019). However, to help identify the most appropriate sleep monitoring method, Figure 13 provides an evaluation of several tools which could be utilised. Further detailed reviews of sleep monitoring methods can be found elsewhere (Halson, 2019; Walsh, et al., 2020). Some of these tools monitor subjective measures of sleep, and others measure/estimate objective measures. Whilst subjective and objective measures should not be compared with each other, they can be monitored and analysed in unison to provide a more comprehensive understanding of an athlete's sleep.

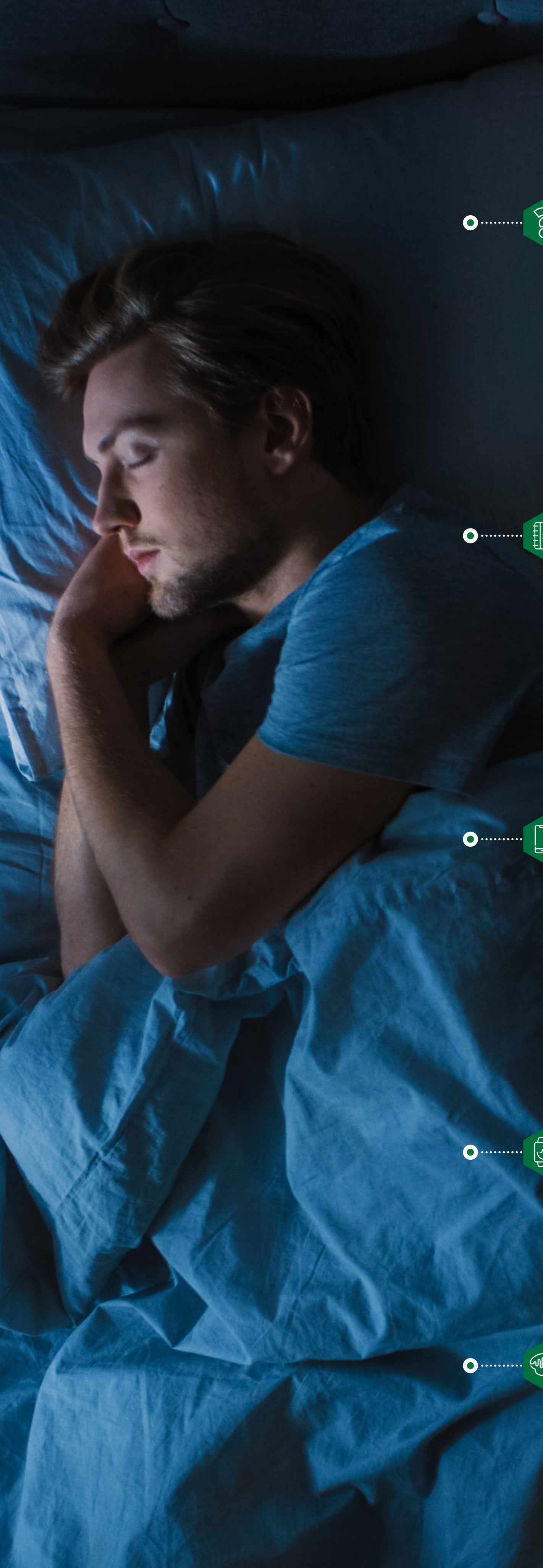
Many commercial sleep monitoring technologies, listed in Figure 13, (e.g. smart watches, smart rings) utilise algorithms to provide sleep 'scores', which are often used to provide feedback on sleep quality. The specific calculations used within the algorithms are often not made publicly available, and are often based off assumptions. Consequently, very little is known about how sleep scores are calculated (Halson, 2019). As a result, feedback from these technologies should be incorporated with caution. In addition, feedback provided can vary between devices, for example between brands of smart watch, or between a mobile device and a smart watch. Therefore, if commercial devices are to be used for sleep monitoring, it is important to be consistent in the use of the same device.

Another tool listed in Figure 12 is the VAS. Figure 14 provides a VAS that could be used to monitor perceived sleep quality. A template VAS which can be adapted depending on the insights of interest, for example, to monitor perceived sleep duration, has also been provided (Figure 15). More information on the use of VAS can be found on page 24.

Using these tools allows for the monitoring of sleep habits over time. Analysis of this longitudinal monitoring allows practitioners to understand an athlete's 'normal' sleep habits. In turn, this enables easy identification of the occurrence of meaningful differences in sleep, e.g. a decrease in sleep quantity or quality, which could result in impaired recovery. This information can be used to help adapt sleep strategies, if required. If serious issues with sleep are identified, the team doctor, or a medical professional should be consulted. Walsh, et al. (2020), provides a flow diagram that documents how sleep monitoring can be used to help optimise and manage sleep for athletes.

**Table 14** ▲

Common sleep terminology and explanations (National Sleep Foundation, 2020; National Sleep Foundation, 2021)



## QUESTIONNAIRES

**Self-assessment tools**

**Questionnaires to assess a range of sleep variables**

*WHEN TO USE*

When limited expertise and funds are available

To screen for factors such as sleep disorders, daytime sleepiness and sleep hygiene

*EXAMPLES*

*Athlete Sleep Screening Questionnaire (Samuels, et al., 2016; Bender, et al., 2018)*

*Athlete Sleep Behaviour Questionnaire (Driller, et al., 2018)*

*Pittsburgh Sleep Quality Index (Buysse, et al., 1989)*

*Epworth Sleepiness Scale (Johns, 1991)*

*Sleep Hygiene Index (Mastin, et al., 2006)*

*Visual Analogue Scale (see Figures 14 and 15)*

*Other subjective ratings – E.g. within a wellness questionnaire*

## SLEEP LOG / DIARY

**Self-assessment tool.**

**Athletes record start and end time for all sleep periods (night-time sleep and daytime naps), as well as subjective sleep quality**

*WHEN TO USE*

When limited expertise and funds are available

To assess sleep schedules

To screen for different sleep factors

*EXAMPLES*

*Multiple available, can be tailored accordingly.*

*Consensus Sleep Diary (Carney, et al., 2012)*

## COMMERCIAL SLEEP TECHNOLOGY
### WEARABLES OR NEARABLES

**Wearable devices that may have sensors in addition to accelerometery (e.g. oximetery, temperature, light, noise)**

**OR**

**Devices that reportedly detect motion when placed on, or near the bed**

*WHEN TO USE*

When limited expertise and funds are available

To increase sleep awareness

*EXAMPLES*

*Smart watches*

*Smart rings*

*Smart phone applications*

## ACTIGRAPHY

**Wearable devices that continuously record body movement, typically using 3-axis accelerometers**

*WHEN TO USE*

For monitoring (typically over 1 – 2 weeks)

*EXAMPLES*

*Wrist or ankle worn devices*

## POLYSOMNOGRAPHY

**Gold-standard**

**A sleep study which typically measures body functions including eye movements, brain activity (EEG), muscle activity and cardiac activity**

*WHEN TO USE*

For suspected sleep disorders

*EXAMPLES*

*Laboratory or home based systems*

**Figure 13**

**Sleep monitoring tools. Adapted from Halson (2019).**

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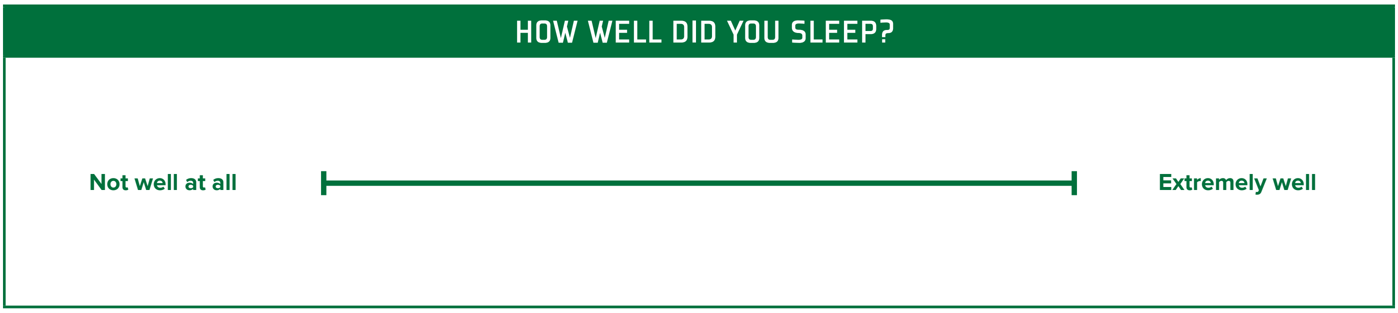
Figure 14
Visual Analogue Scale for monitoring subjective sleep quality.



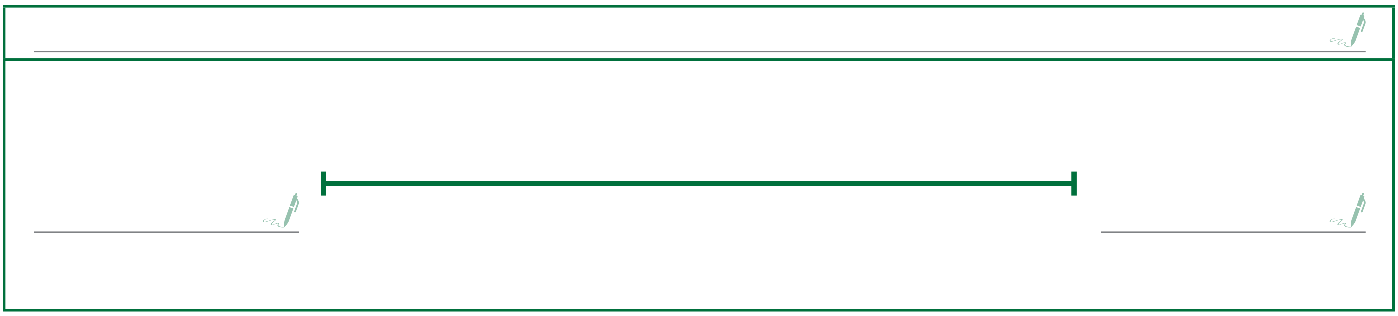



Figure 15
Template Visual Analogue Scale. To be edited and utilised dependent on the insights of interest.

## MENTAL FATIGUE

Mental fatigue is defined as a psychobiological state that arises during prolonged demanding cognitive activity and results in an acute feeling of tiredness and/or a decreased cognitive ability (Williams, et al., 2002; Habay, et al., 2021). Monitoring psychological variables of fatigue and recovery is important given fatigue in sport is not just a result of physiological demands, but also psychological demands. Athletes have reported several causes of mental fatigue, including travel, an inability to switch off from the sport, long team meetings, and internal pressure to succeed (Thompson, et al., 2022). This is in addition to psychological fatigue caused by the demands of competition itself (Coutts, 2016), or fatigue as a result of the daily demands of life.

### PERCEPTUAL ASSESSMENTS

Athletes and members of the sports performance team have reported a number of perceived symptoms linked to mental fatigue (Figure 16) (Russell, et al., 2019). The observation of any of these symptoms may indicate the presence of mental fatigue. Further investigation can help to understand the cause of mental fatigue and/or rule out other causes of these symptoms. Further investigation may be carried out via athlete conversations, or the use of additional monitoring tools.

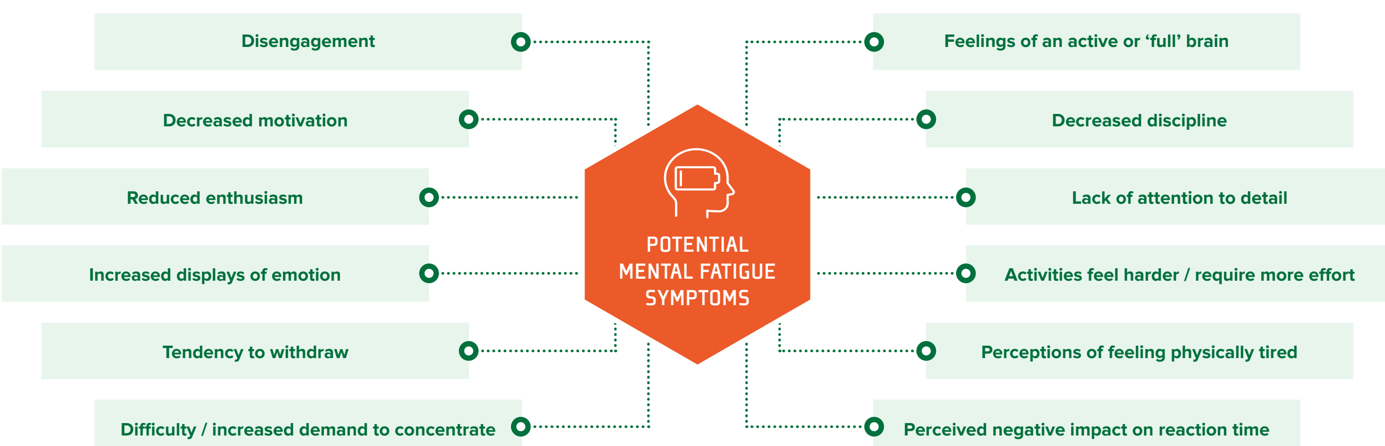



Figure 16
A selection of self-reported mental fatigue symptoms from athletes and members of the sports performance team (Russell, et al., 2019).

In addition to symptom monitoring, there are several tools that can be used to monitor psychological variables, such as stress, anxiety and motivation, and sensations, such as 'hopeful', 'neutral' and 'hopeless', for example. However, to date, the most valid and reliable scale, or combination of scales as methods of assessment are unknown (Russell, et al., 2023). An understanding of an athlete's perception of mental fatigue can also be gained through regular conversations with athletes. However, this might not be feasible/efficient on a daily basis, given the demands of the sports performance team, and number of athletes within teams.

Some of the tools that can be used include questionnaires (see Page 23). In addition to questionnaires, these variables can be monitored via daily wellness surveys (see pages 36 - 37). An increase in stress, anxiety, or feelings of hopelessness, or a decrease in motivation may be a result of increased psychological demands, and may indicate mental fatigue. Visual analogue scales are also practical methods for assessing mental fatigue (Smith, et al., 2019). Figure 17 provides an example of a VAS to monitor mental fatigue. A template VAS which can be adapted depending on the insights of interest, for example, to monitor athletes' stress levels, is also provided (Figure 18). More information on the use of VAS can be found on page 24.

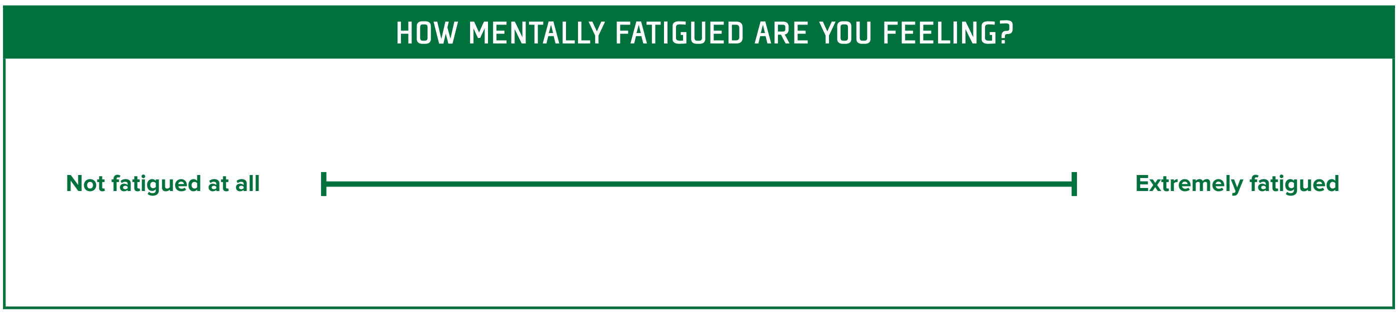



**Figure 17**

Example visual analogue scale to help monitor mental fatigue

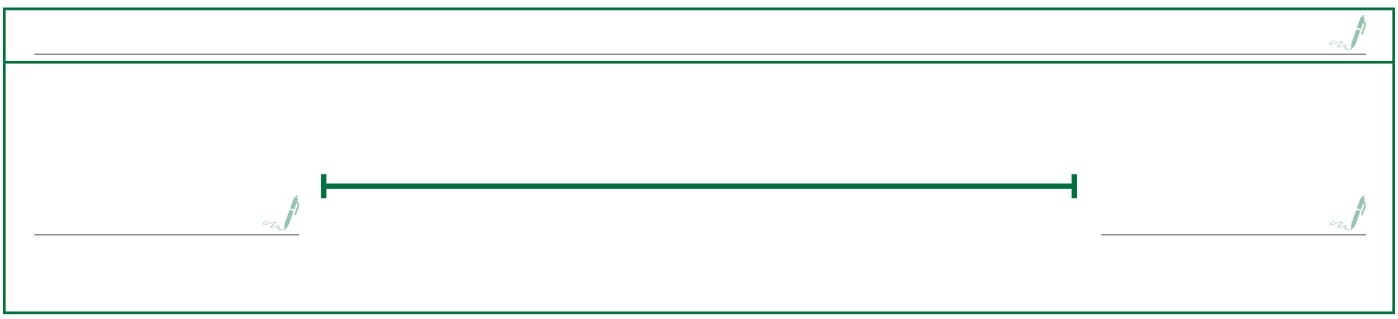


**Figure 18**

Template visual analogue scale. To be edited and utilised dependent on the insights of interest.

## BEHAVIOURAL AND PHYSIOLOGICAL ASSESSMENTS

In addition to subjective (perceptual) assessments of mental fatigue, discussed above, behavioural (i.e performance on a cognitive task) and (neuro)physiological markers (i.e. brain activity), can also be used  (Russell, et al., 2023).

Behavioural markers of mental fatigue can be measured using short cognitive tasks, such as a 3 minute psychomotor vigilance test (PVT) (Grant, et al., 2017; Russell, et al., 2023), or performance-based, sports specific tasks. Given different sports will have different fatigue-inducing mechanisms, the different performance-based, sports specific tasks are not discussed here. Instead, the literature may be reviewed, relevant to the specific sport.

Potential methods to analyse physiological markers include the use of markers of HRV, electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). However, further research is required to evaluate their feasibility in monitoring mental fatigue (Russell, et al., 2023).

Together, monitoring mental fatigue can help analyse an athlete's level of fatigue and recovery status, to inform readiness, and help identify athletes for whom recovery strategies may require adapting.

## WELLNESS SURVEYS

Wellness surveys are simple, practical methods to collect data from athletes on a daily basis. Wellness surveys are completed at the beginning of the day to identify individuals who may need to have their daily training or recovery programs modified. This approach can also help build individual profiles when collecting longitudinal data.

Trends in the data can be monitored to identify meaningful changes in perceived wellness (fatigue, recovery, sleep, etc). In turn, this information can be used to review the impact of, or indeed adapt, training and recovery programs. Page 37 contains an example of a wellness survey. However each prompt and anchor on the survey can be edited to suit the needs of the sport and monitoring strategies. Wellness surveys can be completed on electronic devices, e.g. tablets at the training facility, or on personal mobile devices, with results sent directly to the relevant member of the sports performance team for ease of data collection and analysis.

This method of monitoring is reliant upon athlete compliance and willingness to provide honest answers. It should be ensured that athletes understand how the data will be used for training/recovery and not for team selection, which is a common misconception.

# DAILY WELLNESS SURVEY

## HOW MUCH PHYSICAL ENERGY DO YOU HAVE?

Low energy — Moderate energy — High energy

0 1 2 3 4 5 6 7 8 9 10

## HOW MUCH MENTAL ENERGY DO YOU HAVE?

Low energy — Moderate energy — High energy

0 1 2 3 4 5 6 7 8 9 10

## HOW MOTIVATED ARE YOU TO TRAIN/PRACTICE TODAY?

Low motivation — Moderate motivation — High motivation

0 1 2 3 4 5 6 7 8 9 10

## HOW MUCH MUSCLE SORENESS DO YOU HAVE?

Low soreness — Moderate soreness — High soreness

0 1 2 3 4 5 6 7 8 9 10

## HOW MUCH NON-TRAINING/PRACTICE STRESS DO YOU HAVE?

Low stress — Moderate stress — High stress

0 1 2 3 4 5 6 7 8 9 10

## HOW MANY HOURS OF SLEEP DID YOU GET LAST NIGHT?

1 2 3 4 5 6 7 8 9 10 11+

## WHAT WAS YOUR SLEEP QUALITY?

GOOD AVERAGE POOR