GATORADE SPORTS SCIENCE INSTITUTE™

SPORTS RECOVERY TOOLKIT

PRACTICAL TOOLS FOR QUALIFIED PROFESSIONALS WORKING WITH ATHLETES

2024

THE GATORADE SPORTS SCIENCE INSTITUTE

LIAM BROWN, MSc

IAN ROLLO, PhD

LB and IR are employees of the Gatorade Sports Science Institute, a division of PepsiCo, Incorporated. The views expressed in this book are those of the authors and do not necessarily reflect the position or policy of PepsiCo, Incorporated.

FOREWORD

"Recovery is complex. In football it is the interaction of a myriad of factors including physical outputs, tactics, performance outcomes, chronic load management, training philosophy, multiple fatigue pathways, organisation culture, and of course time. When you play a game every 3-4 days, you can't win trophies without doing it well, but you must also accept that full recovery, by definition, will frequently be incomplete. There are a host of tools that support the acceleration of the process, and our understanding of appropriate protocols is advancing year on year. However, the most important aspect of the Recovery conundrum is not the evolving science behind the protocols we employ – it's the human beings at the centre of the process. Truly personalised recovery strategies are a key foundation on which consistent physical performance is built."

DONOUGH HOLOHAN

Head of Physical Performance at Manchester City Football Club Men's First Team: 2022 - Present

TABLE OF CONTENTS

SPORTS RECOVERY TOOLKIT

Whilst the physiological and psychological demands of sports vary, a common factor for all athletes is the need to recover from training and competition.

The Gatorade Sports Science Institute (GSSI) has a long history of working with the best practitioners, teams, and athletes in the United States and across the globe. The provision of this service is made possible by the translation of sports science research into practice.

Over the last 40 years, GSSI have provided free Sports Science Exchange (SSE) articles which review the latest scientific evidence on core and hot topics in sports nutrition and sports science. To translate the information gained via research, the GSSI provides translational online "tools" for athletes and qualified professionals in sport to utilise in practice. One such example is the GSSI Sports Nutrition Toolkit.

We recognise that sports nutrition is one of multiple recovery strategies now offered to athletes. Thus, the aim of this Sports Recovery Toolkit is to provide a guide to better understand the common recovery strategies used in sport. In addition, opportunities will be shared for the integration of sports nutrition to complement the recovery modality of choice. The toolkit is not designed to cover all topics in sports recovery. Nor should the toolkit be considered as a consensus for best practice in sports recovery. Instead, the toolkit aims to provide introductory materials to support evidence informed practice.

It is our ambition that these resources are taken, modified and adapted to the needs of the individual athlete, team or sport. In doing so, we hope to benefit the recovery of all athletes in pursuit of supporting sustained performance and well-being.

LIAM BROWN, MSc
GSSI Scientist
GSSI International, UK

DR IAN ROLLO
GSSI Principal Scientist:
Head of GSSI International Service, UK

DEFINITION OF TERMS

Table 1 provides common terminology and corresponding definitions used when discussing recovery. Many of these terms do not have 'official' definitions and some terms may have multiple definitions. Thus, these definitions are provided for guidance only.

RECOVERY TERM	DEFINITION / EXPLANATION
Recovery	A multifaceted (e.g. physiological, psychological) restorative process relative to time. An umbrella term, which can be further characterised by different modalities of recovery such as regeneration or psychological recovery strategies.
Passive Recovery	Methods ranging from the application of external methods (e.g. massage), to implementing a state of rest characterised by inactivity.
Active Recovery	Mainly physical activity aimed at compensating the metabolic responses of physical fatigue (e.g. cooldown jogging).
Proactive Recovery	Implies a high level of self-determination by choosing activities customised to individual needs and preferences (e.g. social activities).
Recovery Status	An individual's biopsychosocial balance.
Under-Recovery	The failure to fulfil current recovery demands. This may be a result of excessively prolonged and/or intense exercise, stressful competition, or other stressors.
Readiness	The relative preparedness of an athlete to accept a load.
Performance	The accomplishment of goals by meeting or exceeding predefined standards.
Fatigue	Tiredness resulting from mental or physical exertion or illness, in sport often manifested as failure to maintain the required or expected force (or power output).
Training	The physical and mental preparation athletes undergo in an effort to optimise performance.
Training Load (Exercise Demands/Volume)	The cumulative amount of stress (physiological, psychological or mechanical) placed on an individual from a single or multiple training/exercise sessions (structured or unstructured) over a period of time.
Training Volume	The product of duration and frequency of training.
Training Intensity	The level of effort an individual exerts during exercise relative to his or her maximum effort, measurable using objective (e.g., heart rate/oxygen consumption) or subjective tools (e.g., rating of perceived exertion).
External Load	Any external stimulus applied to athletes that is measured independently of their internal characteristics.
Internal Load (Physiological response)	Load measurable by assessing internal response factors within the biological system, which may be physiological, psychological, or other.
Periodisation	A framework for planned and systematic variation of training parameters with the goal of optimising training adaptations specific to a particular sport, often targeting a specific timeframe or date.
Adaptation	A positive change in the biological system in response to external loading and adequate subsequent recovery.
Maladaptation	A negative change in the biological system in response to external loading and/or inadequate recovery.
Functional Overreaching (Overreaching)	An accumulation of training and/or non-training stress resulting in short-term decrement in performance capacity with or without related physiological and psychological signs and symptoms of maladaptation in which restoration of performance capacity may take from several days to several weeks.
Non-Functional Overreaching	Training-specific negative psychological and hormonal alterations (maladaptation) and subsequent decreased performance as a result of continued overreaching, without sufficient recovery.

Table 1

Common recovery terminology and definitions (Kellmann, 2002; Meeusen, et al., 2013; Soligard, et al., 2016; Kellmann, et al., 2018).

IMPORTANCE OF RECOVERY

Exercise, alongside the demands of daily life, causes physiological and psychological fatigue for an athlete. Allowing athletes to experience a level of stress, causing fatigue, overload, and/or overreaching, is essential to drive adaptation and therefore enhance performance over time (Thorpe, 2021).

Adequate recovery following exercise has been shown to allow the restoration of physiological and psychological processes, allowing athletes to compete or train repeatedly at an appropriate level. On the other hand, inadequate recovery may lead to non-functional overreaching, and in turn, impaired performance. Continued insufficient recovery may result in prolonged decrements in performance, and symptoms of maladaptation (Meeusen, et al., 2013; Kellmann, et al., 2018).

A balance between exercise (training, competition), stress (life demands, etc), the resultant fatigue, and recovery is difficult to achieve in both professional and amateur athletes. Recovery is therefore recommended to be a regular component of an athlete's training schedule. Figure 1 highlights how training may impact recovery and performance.

PROCESS	TRAINING (OVERLOAD)	INTENSIFIED TRAINING →		
Potential Outcome	Acute Fatigue	Functional Overreaching	Non-Functional Overreaching	Maladaptation and Prolonged Decrements in Performance
Recovery	Hours / Day(s)	Days – Weeks	Weeks – Months	Months +
Performance	Increase	Temporary performance decrement	Stagnation Decrease	Decrease

Figure 1

Possible presentation of different stages of training and recovery. Adapted from Meeusen, et al. (2013).

Each athlete will have unique recovery requirements. This is in part due to different physiological and psychological demands between and within sports, as well as the individual response to those demands. Sport specific demands will also dictate the timetable for recovery, with recovery requirements changing depending on the duration between consecutive bouts of exercise. Understanding these demands is key when planning the appropriate methods to monitor and support recovery. Examples of factors that may impact the competitive schedule, and thus subsequent time available for recovery are listed below:

MESOCYCLE
Off-season vs pre-season vs competition

COMPETITION TYPE
Domestic vs international

LEVEL OF PERFORMANCE
Remaining or being eliminated from cup competitions

Table 2 provides examples of training and competition schedules for different sports, highlighting the differences in time available for recovery (or recovery window). Additional factors should also be considered when developing a recovery strategy. These include, but are not limited to, travel commitments and the type, intensity and duration of exercise within each day. As such, there is no one-size-fits-all approach towards recovery. Accordingly, the choice of recovery modalities and strategies should be individualised and follow an athlete centered approach.

SPORT	COMPETITION SCHEDULE	DAY OF MICROCYCLE						
		1	2	3	4	5	6	7
American Football (National Football League)	Typical in-season weekly schedule	Competition	Training	Rest	Training	Training	Training	Training
American Football (Collegiate)	Typical in-season weekly schedule	Rest	Training	Training	Training	Training	Training	Competition
Basketball (National Basketball Association)	Typical in-season weekly schedule	Competition	Training	Competition	Training	Competition	Rest	Competition
Basketball (Collegiate)	Typical in-season weekly schedule	Rest	Training	Competition	Training	Training	Training	Competition
Baseball (Major League Baseball)	Typical in-season weekly schedule	Competition	Competition	Competition	Competition	Rest	Competition	Competition
Ice Hockey (National Hockey League)	Typical in-season weekly schedule	Training	Competition	Competition	Rest	Competition	Training	Competition
Soccer (English Premier League and Women's Super League)	In-Season; 1 game week	Rest	Rest	Training	Training	Training	Training	Competition
	In-Season; 2 game week	Competition	Rest	Training	Training	Training	Training	Competition
	In-Season; 3 game week	Competition	Rest	Training	Competition	Rest	Training	Competition
Cycling (Tour De France)	1 week, no rest day	Competition	Competition	Competition	Competition	Competition	Competition	Competition
Swimming (Olympic 100 & 200m Butterfly)	Competition week	Rest	Competition	Competition	Rest	Competition	Competition	Rest

Competition Training Rest

Table 2

Examples of typical competitive microcycles for a range of different sports. These are examples only and microcycles will differ depending on different circumstances.

GATORADE SPORTS SCIENCE INSTITUTE™

ATHLETE CENTERED APPROACH

The recovery modality selected by an athlete or team is often dictated by the expertise of the responsible practitioner (e.g. coach, trainer, sports nutritionist, sports psychologist). However, an important consideration is how separate recovery modalities may complement each other.

Biopsychosocial factors are important in the recovery process, thus experimenting with complementary approaches may enhance athletes' perceptions of well-being and the overall recovery experience. Unfortunately, specific guidance on how to integrate recovery strategies in ways that benefit athletes is lacking. To ensure that athletes are physically and psychologically ready to exercise again, when required to do so, is likely optimised by an adopting an interdisciplinary approach. This integration of disciplines is understood to achieve outcomes (including new approaches) that could not be achieved within the framework of a single discipline. One such foundational concept is that any recovery strategy employed is not exclusive to the physiological or psychological domain.

To this end, recovery programs should consider athlete-centered approaches, in which individuals are empowered to understand and lead in the planning their own recovery schedules. Giving athletes the skill of self-regulation is important in the adherence to advice for recovery. Three relevant self-regulatory skills for post-exercise recovery, include: 1. self-monitoring, 2. regulation of thoughts and emotions, and 3. self-control. As a translational tool to encourage this behaviour, athletes can be offered a suite of recovery options. These different recovery options can be 'scored'. Specific weighting of scores can be adjusted based on athlete / team priorities or practitioner experience. Figure 2. provides an example, and guide as to building strategies to your own needs.

Figure 2

Recovery strategy scoring template. Scores and recovery options to be added by practitioner depending to on athlete or team priorities or practitioner experience. Examples of relevant recovery options can found in Table 3, but can also be added by the practitioner. Selected recovery options can be added into the blank boxes, as per 'Sleep', 'Recovery Meal' and 'Relaxation'. Timings may also be added, e.g. '15 minute cycle'. The practitioner can then assign each of the chosen recovery options with 10 or 20 points, depending on priorities, adding the values into the associated circles. Once completed, the figure can be used to select recovery modalities, aiming for 100 points.

EXAMPLES OF RECOVERY OPTIONS

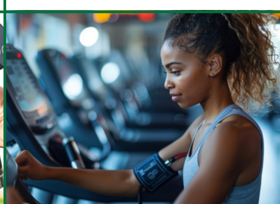
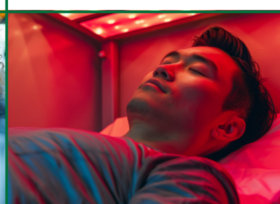
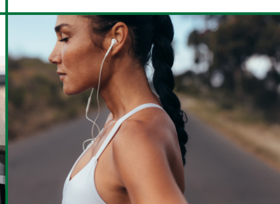
				
RECOVERY SHAKE	PRE-SLEEP PROTEIN	CONTRAST WATER THERAPY	COLD WATER IMMERSION	WHOLE-BODY CRYOTHERAPY
				
MOBILITY SESSION	LIGHT CYCLE	SWIM	JOG	MASSAGE
				
FOAM ROLL	COMPRESSION GARMENT	STRETCHING	HOT WATER IMMERSION	COMPRESSION BOOTS
				
MASSAGE GUN	BLOOD FLOW RESTRICTION	FAR INFRARED RADIATION	GOAL SETTING	TIME WITH FRIENDS
				
DEBRIEFING	COUNSELLING	MEDITATION	YOGA	MINDFULNESS
				
BREATHWORK	'TIME OUT' PERIODS FROM TRAINING	MUSIC	MENTAL IMAGERY	EXPOSURE TO RESTORATIVE ENVIRONMENTS

Table 3

Examples of recovery options (in no particular order)

RECOVERY PLANNING

To help develop recovery strategies individualised to weekly demands, a recovery planning template is provided. This template can be used to list appropriate recovery modalities across different microcycles within a season. The content within this toolkit can be used as a guide to identify appropriate recovery modalities, utilising the athlete centered approach.

STEP 1

List the different microcycles experienced by the team/athlete across the top of the table. For example, for Soccer: add microcycles for the off-season, the pre-season, 1-, 2- and 3-game weeks, and weeks containing competitive finals. Multiple pages of the template can be used if required. Within each microcycle, list which days of the week are typically rest, training, or competition days.

STEP 2

Under each day, within each microcycle, list appropriate recovery modalities. These should be based on the specific demands dictated by the type of microcycle, and the specific schedule.

	TYPE OF MICROCYCLE:	TYPE OF MICROCYCLE:	TYPE OF MICROCYCLE:
DAY 1	Type of day:	Type of day:	Type of day:
DAY 2	Type of day:	Type of day:	Type of day:
DAY 3	Type of day:	Type of day:	Type of day:
DAY 4	Type of day:	Type of day:	Type of day:
DAY 5	Type of day:	Type of day:	Type of day:
DAY 6	Type of day:	Type of day:	Type of day:
DAY 7	Type of day:	Type of day:	Type of day:

THE RECOVERY TEAM

Recovery is a multifactorial process. There is a fundamental role in this process for every member of an athlete's multidisciplinary support team. Together, the team aims to ensure that athletes are mentally and physically prepared for their following training session or competition.

The multidisciplinary team, often referred to as the sports medicine/performance team, is the network of individuals who support athletes' health, performance development and recovery. Collaboration between these individuals may result in improved recovery that would not be achieved by a single discipline alone. Figure 3 provides examples of how each member of the team can influence an athlete's recovery.

HEAD COACH AND COACHING STAFF

Liaise with Head of Performance to understand recovery requirements, modifying training accordingly.

Inform team choices based on player readiness.

TEAM DOCTOR

Monitor historical / pre-existing medical conditions / injuries, and inform team to modify recovery strategies accordingly.

Assess blood profiles to help monitor recovery.

ATHLETIC TRAINER / PHYSIOTHERAPIST

Lead rehabilitation programs.

Lead relevant recovery strategies post-exercise e.g. massage.

Inform athlete of exercises to support recovery.

STRENGTH AND CONDITIONING COACH

Plan / lead warm down exercises.

Plan / lead recovery day exercises.

Periodise/modify exercises based on recovery requirements.

SPORT SCIENTIST

Lead monitoring of recovery.

Lead development of group and personalised recovery strategies.

Modify training based on recovery requirements.

SPORT NUTRITIONIST

Work with sport scientist to integrate sport nutrition into recovery strategies.

Work with chef to develop post-exercise, and match day+1 recipes and menus.

Educate chefs on importance of nutrition in recovery.

Develop athlete specific recovery supplement strategies.

Modify athlete nutrition strategies based of blood results.

SPORT PSYCHOLOGIST

Supporting monitoring of recovery (i.e. mental recovery).

Support athletes with mental fatigue / mental well-being.

PERFORMANCE CHEF

Partner with sport nutritionist to develop recovery recipes and menus.

Provide education / informed options to athletes at point of food service.

Figure 3

Examples of how the sports performance team can influence an athlete's recovery. Space is included to list the names of recovery stakeholders for a specific athlete/team. (See pages 7 – 9 on integrating these disciplines).

Table 4 can be used to list recovery priorities, specific to the individual practitioner's role within the sports performance team. It should be considered how these priorities align with the different stakeholders with in the team.

RECOVERY PRIORITIES

PRACTITIONER'S ROLE: ______________________________

RECOVERY PRIORITY	RELEVANT STAKEHOLDER(S)	COMMENTS
E.g. Post-game recovery nutrition	Performance Chef, Sport Scientist	Ensure home and away post-match menus are aligned on a weekly basis

Table 4

Space to list recovery priorities. An example priority has been included for a Nutritionist / Dietitian.

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?		

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?

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.

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).

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

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.

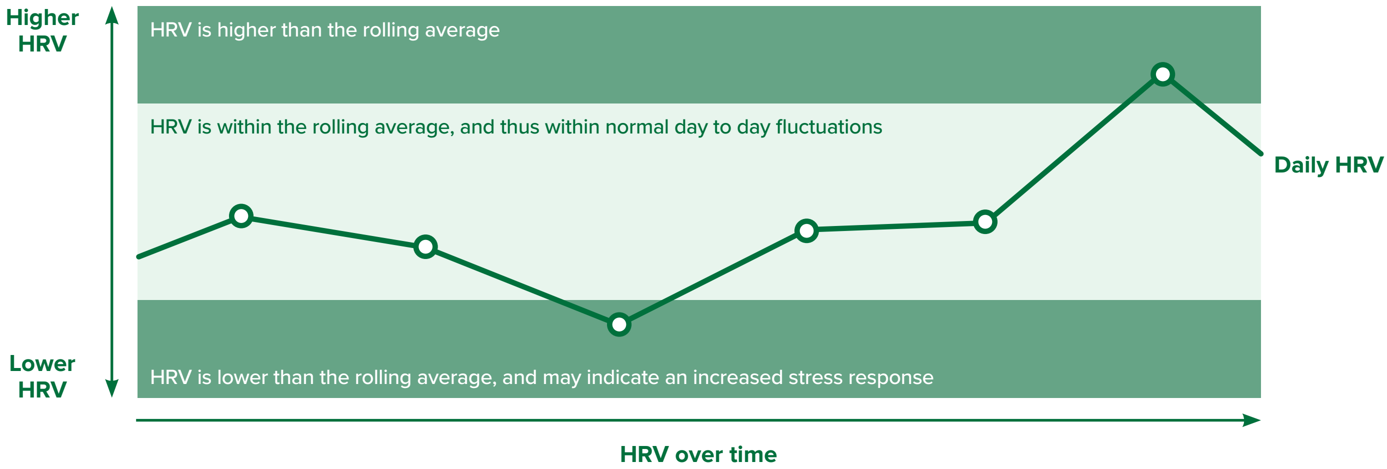
Together, indicators of Autonomic Nervous System (ANS) function, in this case HR, HRR and HRV, can be used to monitor athlete stress, fatigue and recovery status to inform readiness and/or potential requirements to adapt recovery strategies. In addition, measures of HR variability may be used as a measure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

Figure 7 ▲

A calculation of Heart Rate Recovery.

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.

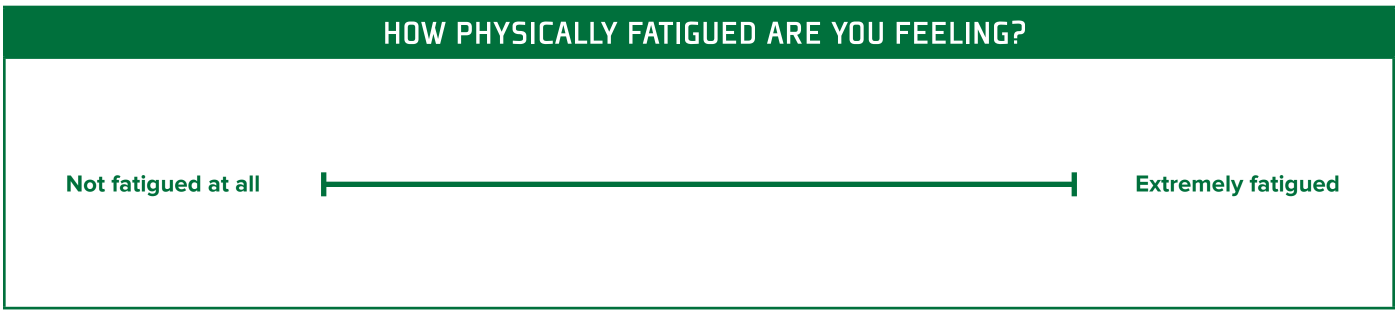
VISUAL ANALOGUE SCALE (VAS)

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.



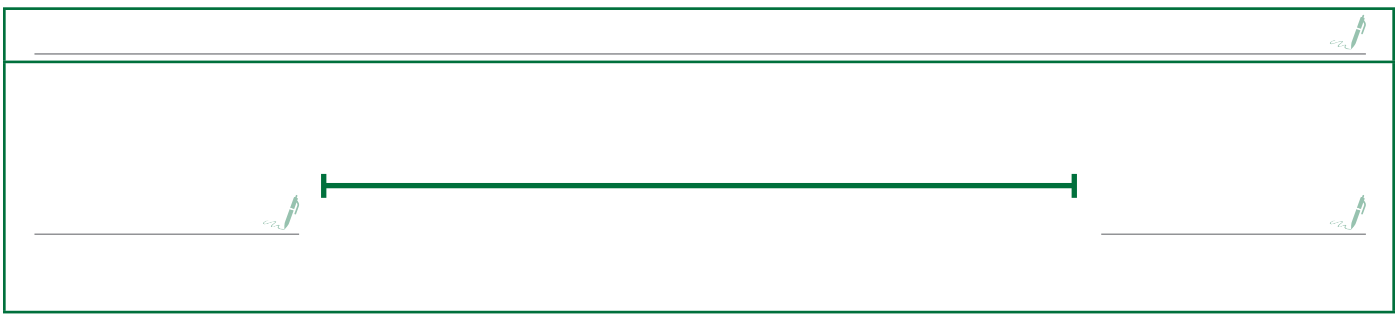


Figure 10

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 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? **For Bloods: See Pedlar, et al., 2019** **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'.

GATORADE SPORTS SCIENCE INSTITUTE™

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.

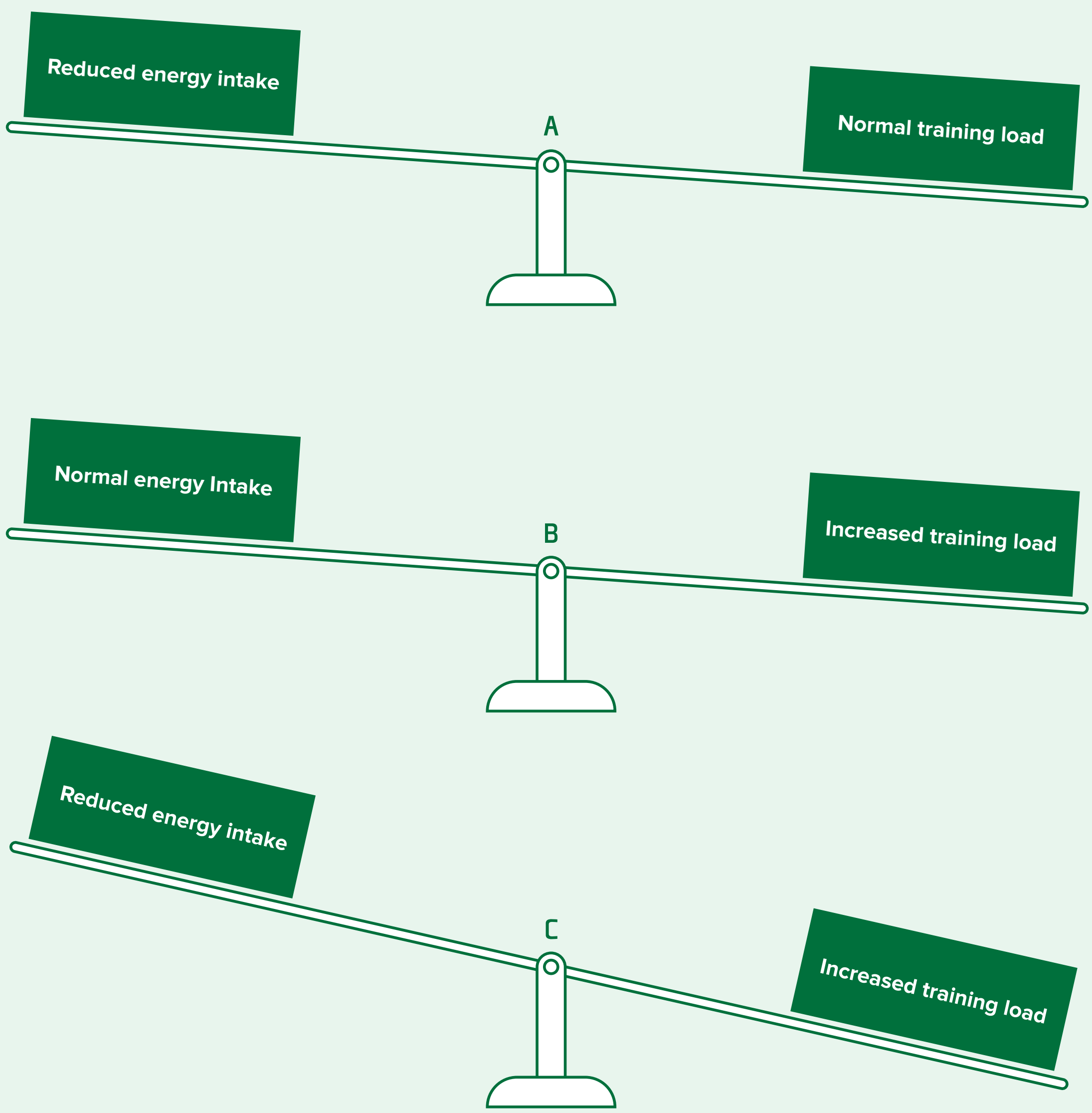


Figure 12

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

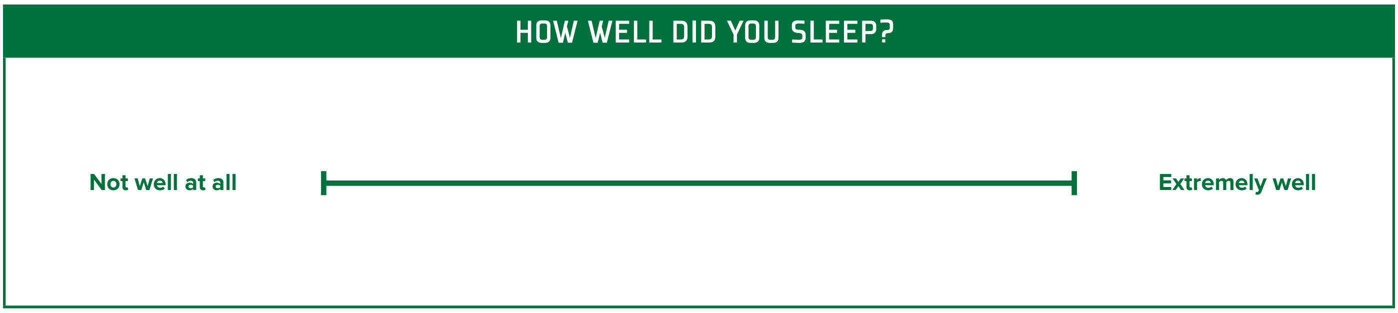
Figure 13

Sleep monitoring tools. Adapted from Halson (2019).

GATORADE SPORTS SCIENCE INSTITUTE™

Figure 14

Visual Analogue Scale for monitoring subjective sleep quality.



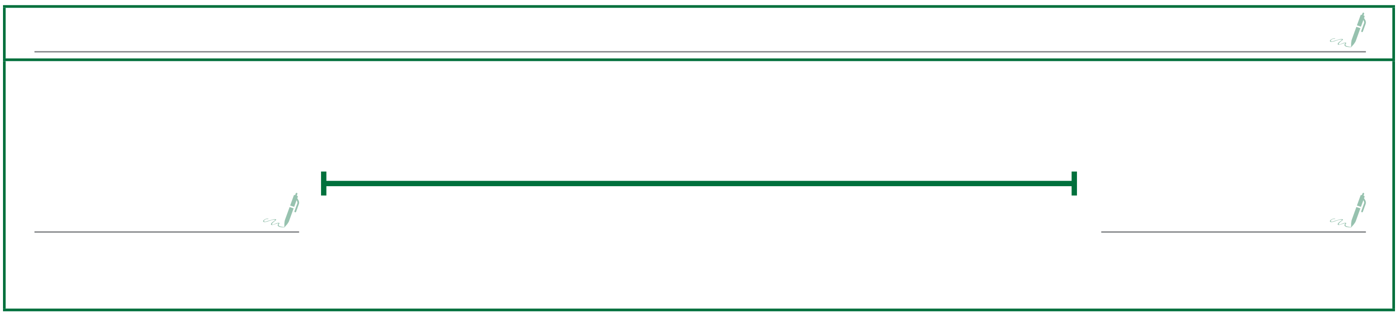


Figure 15

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.

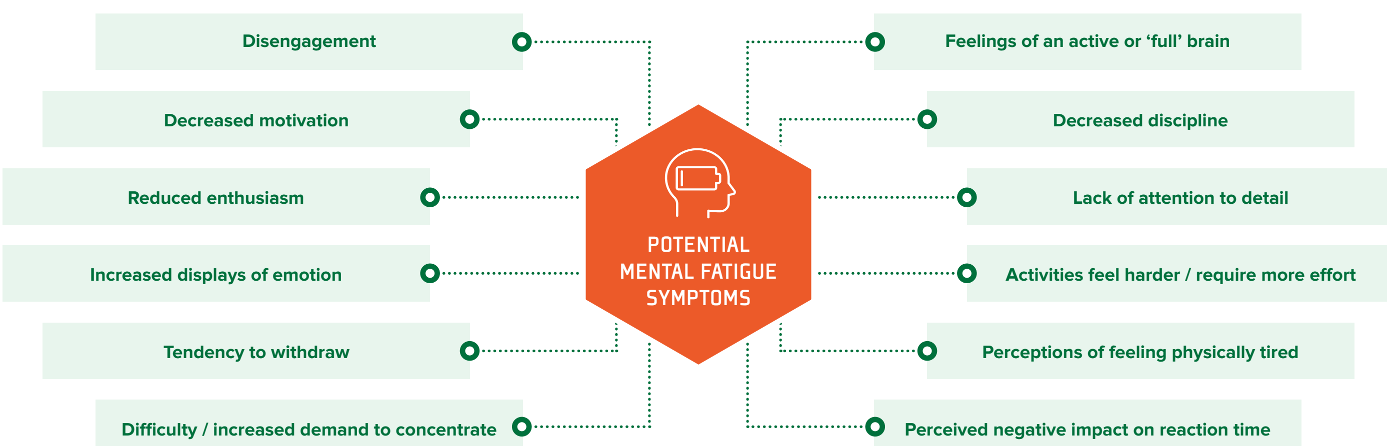


Figure 16

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.

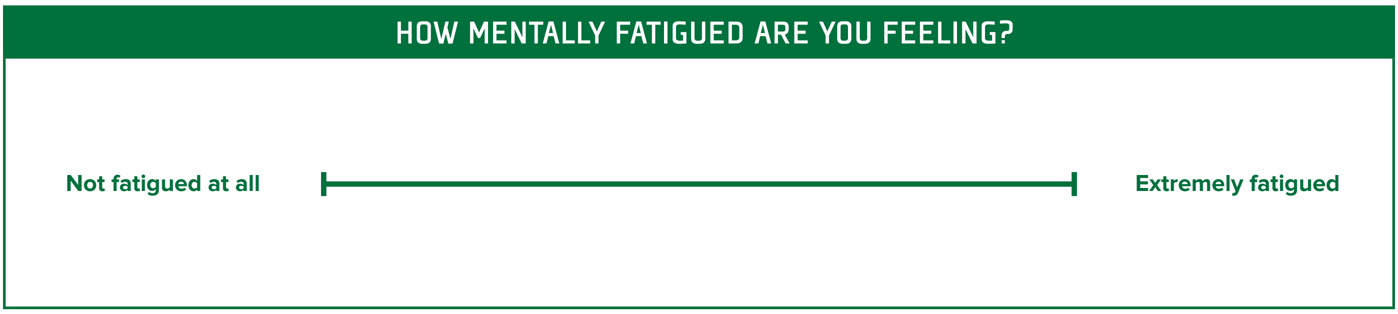


Figure 17
Example visual analogue scale to help monitor mental fatigue

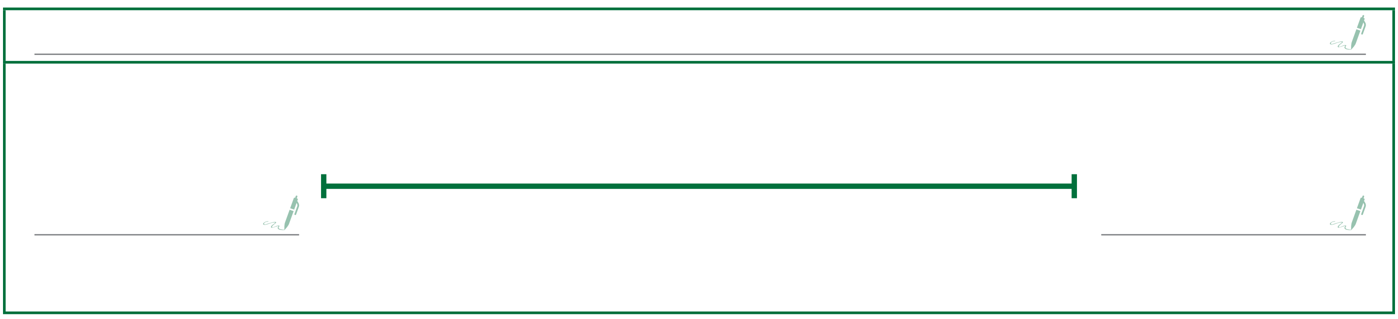


Figure 18
Template visual analogue scale. To be edited and utilised dependent on the insights of interest.

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

RECOVERY MODALITIES

Every athlete will experience a period of recovery following exercise. During this time the approach to individual recovery needs will primarily depend on when athletes are required to perform again. The demands of previous and upcoming bouts of exercise are also important considerations. There are a range of recovery modalities that can be utilised to support an athlete's recovery. The aim of this chapter is to provide an overview of the common recovery modalities used in sport.

The process of recovery is complex and multifaceted. Each recovery modality will have different protocols, mechanisms of action and potential benefits or outcomes. Understanding the demands of exercise (Pages 12 - 37) can help identify which recovery modality (or multiple modalities) are best suited to support the needs of the individual athlete. Indeed, there is no one-size-fits-all approach to recovery, given the different mechanisms involved in both fatigue, and recovery. Table 15 provides a checklist of factors to consider to help build a relevant and sustainable recovery strategy, specific to each athlete.

As a general guide, the different recovery modalities can be considered on a hierarchical basis (Figure 19). Given the strength of scientific evidence, it is recommended to first ensure nutrition and sleep practices are optimised, and training schedules are adjusted strategically, ensuring sufficient periods of rest, before the use of additional recovery modalities are considered. The following pages provide tools and guidance to support the development of appropriate and feasible recovery strategies.

Introducing a new recovery strategy, or adapting a previous strategy, may be a big change for an athlete. To help with this, methods to promote athlete behaviour change can be considered. Three key behaviour change principles have been shared elsewhere by Lindsay & Pitt (2022).

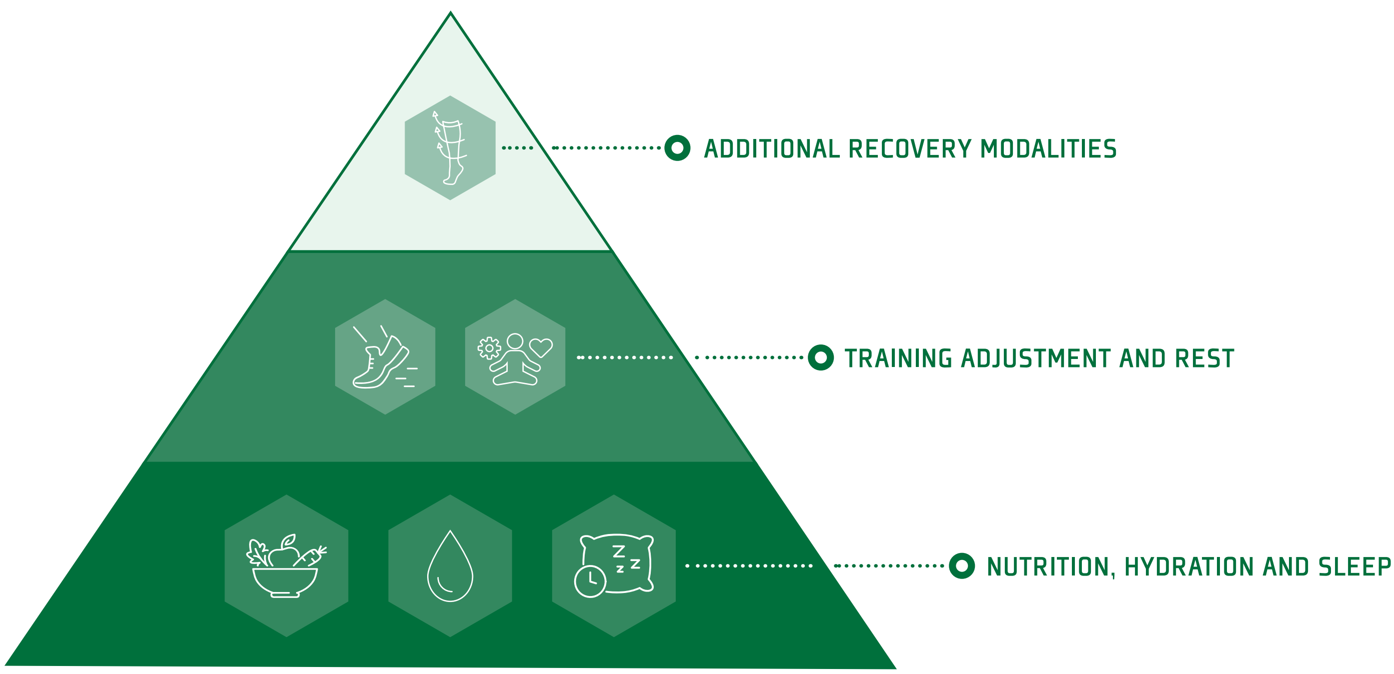


Figure 19

The Recovery Pyramid.

RECOVERY STRATEGY CONSIDERATION	YES/NO*	COMMENTS
WHY IS RECOVERY REQUIRED?		
Is there a clear rational as to why recovery is required?		
WHAT WILL BE THE AIM OF RECOVERY?		
Is there a clear rational as to if it is physiological and/or psychological recovery that is required?		
Is there a clear understanding of the relevant mechanisms of fatigue?		
HOW EFFICACIOUS IS THE RECOVERY MODALITY?		
Have nutrition, sleep, and training strategies been optimised to support recovery?		
Is there scientific evidence to support the use of the recovery modality for the specific aim?		
Is there scientific evidence to support the use of the recovery modality within the required recovery window? i.e. are benefits reported after 1h or 24h		
Is there scientific evidence to support the use of the recovery modality in the relevant population? i.e. evidence in elite athletes		
HOW FEASIBLE IS THE RECOVERY MODALITY TO USE?		
Are there facilities available to enable the use of the recovery modality? i.e. does the training centre have cryotherapy chambers / can these be accessed elsewhere?		
Does the practitioner have the knowledge/ experience to implement the recovery modality?		
Is there a clear protocol in place for the use of the modality?		
Is the modality simple for athletes to use?		
Is there sufficient time for athletes to engage with the modality?		
Can the modality be utilised effectively remotely? i.e. away from the training centre, at the stadium, or whilst travelling		
Has the protocol taken into account any evidence that may suggest the modality may be enhanced / impaired if combined with additional recovery modalities, if relevant?		
Is the modality sustainable from a human resource, time, and financial point of view?		

WHEN WILL RECOVERY OCCUR?		
Is there a clear rational as to when the recovery modality will be used?		
Has the protocol taken into account any potential negative impact of the recovery modality on subsequent performance, depending on timings?		
Will the system be used frequently enough to support recovery, without reducing compliance?		
Has the protocol taken into account any potential impact of the recovery modality on long-term adaptation, if this is a concern in the specific situation?		
HOW WILL RECOVERY BE MONITORED?		
Is there a clear rational as to how the efficacy of the recovery modality will be monitored? (See 'Monitoring to Support Recovery' section)		
Is there a clear rational as to how often the use of the recovery modalities will be monitored?		
HOW WILL FEEDBACK BE PROVIDED / RESULTS UTILISED?		
Is there a protocol in place to adapt the recovery modality if it is not working as required?		
Is there a plan to collect data to inform future recovery strategies?		

Table 15 ▲

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

NUTRITION

Alongside sleep, nutrition is at the foundation of the recovery process (Figure 19). Post-exercise, the body needs to restore the depleted energy substrates (carbohydrate and fats (intramuscular triglyceride)) (metabolic recovery), and repair any damage to the skeletal muscle (mechanical recovery) (Heaton, et al., 2017). Nutrition plays a key role in both recovery phases. Indeed, nutrition can help protein muscle regeneration, glycogen resynthesis, the reduction of fatigue, and support physical and immune health (Heaton, et al., 2017). All of which are factors contributing to recovery, and subsequent readiness. As such, optimal nutrition should be encouraged, and regularly reinforced with athletes (Meeusen, et al., 2013).

This section will provide tools and guidance to help support athletes' recovery through the utilisation of nutrition practices. Though this section is broken into individual macronutrients, micronutrients and hydration, utilising a combination of these practices will have a greater impact that utilising one in isolation. It is not the aim of this toolkit to provide an exhaustive list of all nutrients and supplements used to enhance recovery, instead it focuses on fundamental dietary strategies.

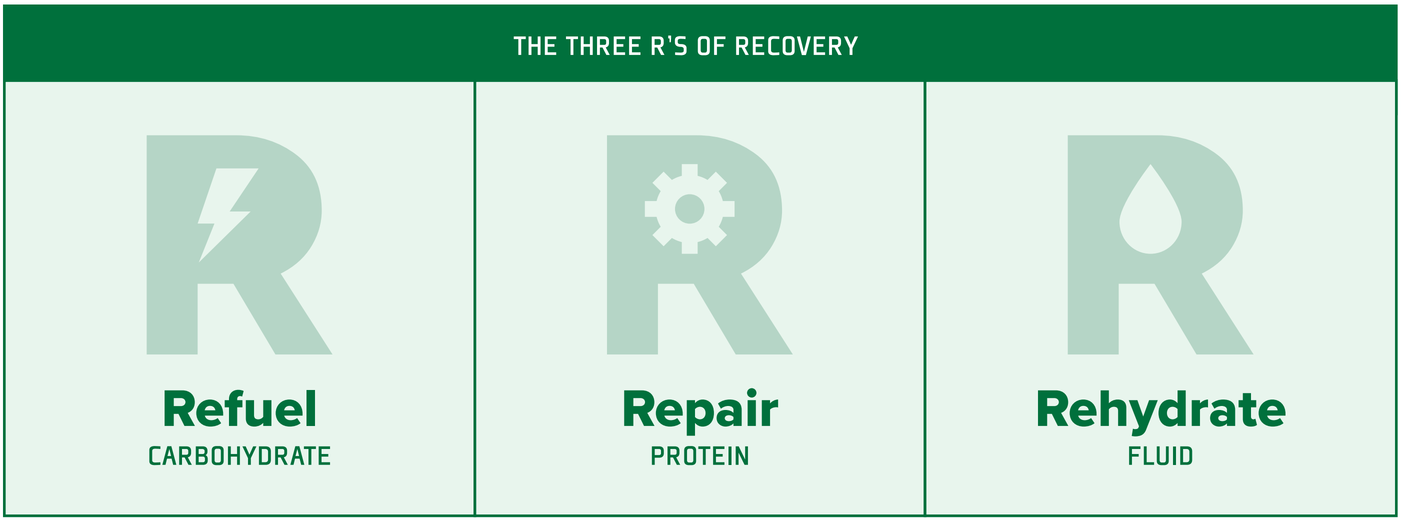
For more information on nutrition, including guidance on how to run a dietary analysis, and athlete consultations, as well as meal planning guidance, see the GSSI Sports Nutrition Toolkit. For information on recovery nutrition for specific sports, a list of GSSI resources are shared below:

- GSSI SSE Article #129: Recovery Nutrition for Football Players (Res, 2014)
- GSSI SSE Article #144: In-Season Recovery Nutrition for American Football (Baar & Heaton, 2015)
- GSSI SSE Article #166: Recovery Nutrition for the Basketball Athlete (Baar, 2016)
- GSSI Sports Nutrition For American Football Book
- GSSI Sports Nutrition for Basketball Book

ENERGY

Energy intake is an important consideration. Energy is expended during exercise, and must be replenished post-exercise to prevent fatigue. An increase in training load will likely increase energy expenditure, thus energy intake should be increased to match these demands. Meeting daily carbohydrate recommendations will ensure sufficient carbohydrate availability to the muscle and central nervous system and contribute to daily energy requirements.

Tools and guidance to help calculate an athlete's energy requirements can be found in the GSSI Sports Nutrition Toolkit.



REFUEL – CARBOHYDRATE

Carbohydrates are the body's main substrate used to provide energy during exercise at moderate to high intensities (Coyle, 2000). However, the human body can only store a limited quantity of carbohydrates, in the form of muscle or liver glycogen, at any one time. The rate at which these stores are depleted is dependent upon the duration and intensity of exercise. Glycogen depletion is a major cause of fatigue (Hearris, et al., 2018). For this reason, carbohydrate consumption is recommended post-exercise to promote recovery of glycogen stores. Meeting carbohydrate recommendations can also help reduce the risk of over-reaching and support immune function (Heaton, et al., 2017).

Figure 20 outlines carbohydrate recommendations for post-exercise refuelling. These recommendations differ depending on the time available for recovery. Specifically there is an increased focus on recovery for athletes with less than 8 hours between two consecutive bouts of exercise. For example those with multiple training sessions within the same day, or taking part in tournaments with back to back games. Tables 16 and 17 convert these recommendations into the total amount of carbohydrate required depending on body mass and exercise intensity. The two tables provide recommendations for carbohydrate consumption in the first four hours post-exercise (for those with <8 hours recovery time), and daily carbohydrate consumption respectively. Table 18 provides examples of 30g and 100g of carbohydrate to help guide the choice of recovery foods and beverages.

Time until next bout of exercise	RECOMMENDATIONS	TIPS AND ADVICE
< 8 hours	1.0 - 1.2 grams of carboydrate per kg body mass per hour for first 4 hours Then continue to work towards daily carboydrate recommendations	Moderate to high glycaemic carbohydrates are recommended Consuming a combination of glucose and fructose-based carbohydrates may better replenish liver glycogen stores
≥ 8 hours	Continue to work towards daily carbohydrate recommendations post-exercise	Timing and type of carbohydrate can be chosen based on individual preferences

Figure 20 ▲

Carbohydrate recommendations for post-exercise refuelling (Thomas, et al., 2016; Wallis & Podlogar, 2022).

Table 16

A guide to post-exercise carbohydrate consumption, for recovery periods of < 8 hours, based on body mass (BM), adapted from Thomas, et al. (2016). A conversion table between kilograms and pounds can be found in the Appendix (Table 25).

CARBOHYDRATE CONVERSION TABLES

Body Mass		Recommended Carbohydrate Intake (g) in the Post-Exercise Period Based on Body Mass	
kg	lb	1 g/kg BM	1.2 g/kg BM
60	132	60	72
65	143	65	78
70	154	70	84
75	165	75	90
80	176	80	96
85	187	85	102
90	198	90	108
95	209	95	114
100	221	100	120
105	232	105	126
110	243	110	132

		Light Intensity Exercise							
				Moderate Intensity Exercise					
					High Intensity Exercise				
Body Mass		Recommended Carbohydrate Intake (g) Per Day Based on Body Mass							
kg	lb	3 g/kg BM/d	4 g/kg BM/d	5 g/kg BM/d	6 g/kg BM/d	7 g/kg BM/d	8 g/kg BM/d	9 g/kg BM/d	10 g/kg BM/d
60	132	180	240	300	360	420	480	540	600
65	143	195	260	325	390	455	520	585	650
70	154	210	280	350	420	490	560	630	700
75	165	225	300	375	450	525	600	675	750
80	176	240	320	400	480	560	640	720	800
85	187	255	340	425	510	595	680	765	850
90	198	270	360	450	540	630	720	810	900
95	209	285	380	475	570	665	760	855	950
100	221	300	400	500	600	700	800	900	1000
105	232	315	420	525	630	735	840	945	1050
110	243	330	440	550	660	770	880	990	1100

Table 17

A guide to daily carbohydrate consumption based on body mass (BM) and activity levels, adapted from Thomas, et al. (2016).

CARBOHYDRATE QUANTITIES

Table 18 presents a selection of commonly consumed foods and beverages that will provide approximately 30 or 100g of carbohydrate. These examples, whilst not practically feasible in all cases, can be used as a guide for adapting quantities to meet an athlete's requirements. There is space within this column for the nutritionist to add foods that are more relevant to the athlete / club / country. A conversion table between grams and ounces can be found in the Appendix (Table 26).

Table 18

Common sources of carbohydrate providing ~30g and 100g respectively. Please note these values are estimates and food/beverage packaging can be reviewed to evaluate actual nutritional content.

~30g

1.5 SERVINGS OF GATORADE
Serving size: 12 fl oz / 540 ml
Carbohydrate: 33 g
Calories: 120 kcal

1 GLASS OF FRUIT JUICE
Serving size: 10 fl oz / 300 ml
Carbohydrate: 30 g
Calories: 140 kcal

1 STICK GATORADE POWDER
Serving size: 17 fl oz / 500 ml
Carbohydrate: 34 g
Calories: 130 kcal

1.5 BAG OF BAKED CHIPS
Serving size: 1.5 oz / 42g
Carbohydrate: 30 g
Calories: 180 kcal

~100g

LARGE PLATE PASTA
Serving size: 10.6 oz / 300 g
Carbohydrate: 100 g
Calories: 515 kcal

LARGE PLATE RICE
Serving size: 10.6 oz / 300 g
Carbohydrate: 95 g
Calories: 430 kcal

LARGE PLATE COUSCOUS
Serving size: 10.6 oz / 300 g
Carbohydrate: 100 g
Calories: 545 kcal

2 LARGE PLATES QUINOA
Serving size: 21.2 oz / 600 g
Carbohydrate: 105 g
Calories: 700 kcal

5 RICE CAKES
Serving size: 1.6 oz / 45 g
Carbohydrate: 32 g
Calories: 160 kcal

HANDFUL OF DRIED MANGO
Serving size: 1.4 oz / 40 g
Carbohydrate: 28 g
Calories: 155 kcal

2 SLICES WHOLEGRAIN BREAD
Serving size: 2.7 oz / 75 g
Carbohydrate: 28 g
Calories: 170 kcal

1.5 MEDIUM BANANAS
Serving size: 7.9 oz / 225 g
Carbohydrate: 30 g
Calories: 90 kcal

1 TORTILLA
Serving size: 1.8 oz / 50 g
Carbohydrate: 25 g
Calories: 150 kcal

1 HANDFUL RAISINS
Serving size: 1.6 oz / 45 g
Carbohydrate: 30 g
Calories: 135 kcal

1 MEDIUM BOWL OF OATMEAL & MILK
Serving size: 7.8 oz / 220 g
Carbohydrate: 27 g
Calories: 250 kcal

HALF A BAGEL
Serving size: 1.6 oz / 45 g
Carbohydrate: 25 g
Calories: 120 kcal

1.5 LARGE ORANGES
Serving size: 10.6 oz / 300 g
Carbohydrate: 30 g
Calories: 150 kcal

2 PANCAKES
Serving size: 2.1 oz / 60 g
Carbohydrate: 30 g
Calories: 150 kcal

2 PLATES OF NOODLES
Serving size: 17.7 oz / 500 g
Carbohydrate: 105 g
Calories: 550 kcal

2 BAKED POTATOES
Serving size: 17.7 oz / 500 g
Carbohydrate: 105 g
Calories: 500 kcal

7 SLICES WHOLEGRAIN BREAD
Serving size: 9.2 oz / 260 g
Carbohydrate: 100 g
Calories: 600 kcal

5 MEDIUM BANANAS
Serving size: 33.5 oz / 750 g
Carbohydrate: 100 g
Calories: 450 kcal

4 TORTILLAS
Serving size: 7.1 oz / 200 g
Carbohydrate: 100 g
Calories: 600 kcal

1 LARGE SWEET POTATO
Serving size: 12.4 oz / 350 g
Carbohydrate: 95 g
Calories: 430 kcal

4 MEDIUM BOWLS OF OATMEAL & MILK
Serving size: 31.1 oz / 880 g
Carbohydrate: 108 g
Calories: 990 kcal

2 BAGELS
Serving size: 6.4 oz / 180 g
Carbohydrate: 95 g
Calories: 500 kcal

5 LARGE ORANGES
Serving size: 35.3 oz / 1000 g
Carbohydrate: 97 g
Calories: 520 kcal

7 PANCAKES
Serving size: 7.4 oz / 210 g
Carbohydrate: 100 g
Calories: 525 kcal

REPAIR – PROTEIN

During exercise, the muscles may experience damage which can negatively impact muscle function and cause delayed onset muscle soreness. Consuming adequate quantities of protein can help repair damaged muscle proteins, providing the substrate for the synthesis of contractile and mitochondrial muscle proteins.

Throughout the day, athletes are recommended to consume approximately 0.25 – 0.3 grams of protein per kg body mass, every 3 – 5 hours (Thomas, et al., 2016). Table 19 highlights the recommended portion of protein per serve, depending on body mass, and Table 20 highlights daily protein recommendations, given recovery does not stop in the first few hours post-exercise.

Muscle protein synthesis will respond in a dose dependent manner to the quantity of protein ingested, and is upregulated for at least 24 hours post-exercise (Burd, et al., 2011). However, athletes typically struggle to ingest large quantities of protein immediately post-exercise, and it is common for appetite to be suppressed. Therefore, a practical approach is to ingest ~20g of high quality rapidly digested protein (whey) as part of a recovery drink (providing fluid and carbohydrate) after exercise (Figure 24), which is then complimented by additional protein intake through foods when appropriate as well as protein intake prior to sleep.

Table 21 provides examples of 20g of protein (approximately 0.25 – 0.3g protein for a 70 – 80kg individual). It is recommended that protein sources are complete, and rich in leucine (typically those of animal origin) (Heaton, et al., 2017). A dietitian/nutritionist can provide recommendations to ensure quality protein is consumed for those who have plant-based diets, where protein sources may not stimulate muscle protein synthesis to the same extent as animal-based proteins, unless particular combinations of proteins containing all of the essential amino acids are consumed together (van Loon, 2021). Page 49 provides a protein timeline that can be used with athletes to evaluate, and in turn help optimise, protein consumption throughout the day.

PROTEIN CONVERSION TABLES

Body Mass		Recommended Protein Intake (g) Per Serve, Depending on Body Mass	
kg	**lb**	**0.25 g/kg BM**	**0.3 g/kg BM**
60	132	15	18
65	143	16	20
70	154	18	21
75	165	19	23
80	176	20	24
85	187	21	26
90	198	23	27
95	209	24	29
100	221	25	30
105	232	26	32
110	243	28	33

Table 19

A guide to protein consumption per serve (meal occasion) based on body mass (BM). Recommendation adapted from Thomas, et al. (2016).

		Increasing Exercise Intensities →								
Body Mass		Recommended Protein Intake (g) Per Day Based on Body Mass								
kg	lb	1.2 g/kg BM	1.3 g/kg BM	1.4 g/kg BM	1.5 g/kg BM	1.6 g/kg BM	1.7 g/kg BM	1.8 g/kg BM	1.9 g/kg BM	2.0 g/kg BM
60	132	72	78	84	90	96	102	108	114	120
65	143	78	85	91	98	104	111	117	124	130
70	154	84	91	98	105	112	119	126	133	140
75	165	90	98	105	113	120	128	135	143	150
80	176	96	104	112	120	128	136	144	152	160
85	187	102	111	119	128	136	145	153	162	170
90	198	108	117	126	135	144	153	162	171	180
95	209	114	124	133	143	152	162	171	181	190
100	221	120	130	140	150	160	170	180	190	200
105	232	126	137	147	158	168	179	189	200	210
110	243	132	143	154	165	176	187	198	209	220

Table 20

A guide to daily protein consumption based on body mass (BM), and activity levels.
Recommendations adapted from Thomas, et al. (2016).

PROTEIN QUANTITIES

Table 21 presents a selection of commonly consumed foods that will provide around, or greater than 20g of protein per serving. These examples can be used as a guide for the nutritionist, with the nutritionist adapting quantities to meet an athlete's requirements. There is space above the images for the nutritionist to add foods that are more relevant to the athlete / club / country. A conversion table between grams and ounces can be found in the Appendix (Table 26).

~20g

1 MEDIUM CHICKEN BREAST
Serving size: 4.2 oz / 120 g
Protein: 38 g
Calories: 175 kcal

1 SMALL SIRLOIN STEAK
Serving size: 3.9 oz / 110 g
Protein: 37 g
Calories: 250 kcal

SMALL PORTION LEAN GROUND BEEF
Serving size: 3.5 oz / 100 g
Protein: 22 g
Calories: 125 kcal

HALF A CAN OF TUNA
Serving size: 3.2 oz / 90 g
Protein: 21 g
Calories: 90 kcal

1 FILLET OF SALMON
Serving size: 3.5 oz / 100 g
Protein: 23 g
Calories: 205 kcal

1 MEDIUM FILLET OF COD
Serving size: 3.6 oz / 100 g
Protein: 24 g
Calories: 100 kcal

1 PLATE PRAWNS
Serving size: 4.2 oz / 120 g
Protein: 21 g
Calories: 90 kcal

3 MEDIUM EGGS
Serving size: 6.4 oz / 180 g
Protein: 21 g
Calories: 215 kcal

1 CONTAINER COTTAGE CHEESE
Serving size: 8.8 oz / 250 g
Protein: 23 g
Calories: 260 kcal

FAT-FREE YOGURT
Serving size: 7.1 oz / 200 g
Protein: 20 g
Calories: 110 kcal

1 LARGE GLASS MILK
Serving size: 20.1 fl oz / 568 ml
Protein: 19 g
Calories: 360 kcal

GLASS CHOCOLATE MILK
Serving size: 17.7 fl oz / 500 ml
Protein: 18 g
Calories: 360 kcal

SKIMMED MILK POWDER
Serving size: 2.1 oz / 60 g
Protein: 21 g
Calories: 210 kcal

1 SCOOP MM 100% WHEY
Serving size: 1.2 oz / 33 g
Protein: 25 g
Calories: 130 kcal

2 SCOOPS EVOLVE PROTEIN POWDER
Serving size: 1.6 oz / 48 g
Protein: 20 g
Calories: 160 kcal

GLASS SOY MILK
Serving size: 17.7 fl oz / 500 ml
Protein: 17 g
Calories: 190 kcal

SEITAN
Serving size: 3.5 oz / 100 g
Protein: 24 g
Calories: 120 kcal

SOY FLAKES
Serving size: 1.8 oz / 50 g
Protein: 27 g
Calories: 200 kcal

TEXTURED SOY
Serving size: 1.8 oz / 50 g
Protein: 24 g
Calories: 160 kcal

LARGE PLATE QUINOA
Serving size: 10.6 oz / 300 g
Protein: 21 g
Calories: 350 kcal

PEANUT POWDER
Serving size: 1.8 oz / 50 g
Protein: 25 g
Calories: 160 kcal

ALMOND PROTEIN POWDER
Serving size: 1.8 oz / 50 g
Protein: 22 g
Calories: 100 kcal

3 SERVINGS OF MIXED NUTS
Serving size: 3.2 oz / 90 g
Protein: 25 g
Calories: 550 kcal

TOFU
Serving size: 3.5 oz / 100 g
Protein: 24 g
Calories: 260 kcal

4 TABLESPOONS PEANUT BUTTER
Serving size: 2.1 oz / 60 g
Protein: 19 g
Calories: 450 kcal

MYCOPROTEIN
Serving size: 7.1 oz / 200 g
Protein: 22 g
Calories: 200 kcal

1 PLATE LENTILS
Serving size: 8.8 oz / 250 g
Protein: 19 g
Calories: 270 kcal

1 CAN CHICKPEAS
Serving size: 8.1 oz / 230 g
Protein: 17 g
Calories: 280 kcal

2.5 SERVINGS EDAMAME BEANS
Serving size: 7.1 oz / 200 g
Protein: 22 g
Calories: 280 kcal

1 CAN BLACK BEANS
Serving size: 14.1 oz / 400 g
Protein: 18 g
Calories: 260 kcal

Table 21

Common sources of protein providing approximately 20g. Please note these values are estimates and food/beverage packaging can be reviewed to evaluate actual nutritional content.

PROTEIN TIMELINE

NAME: ______________________ DATE: ______________

TYPE OF DAY (E.G. TRAINING DAY): ______________________

Three T's should be taken into account when evaluating protein intake: 'Total' amount, 'Timing' of intake, and 'Type' of protein consumed. To evaluate intake, the athlete can record a daily training or competition schedule on the 'Exercise Schedule' timeline and their daily protein consumption on the 'Current Protein Consumption' timeline. The nutritionist can then evaluate intake against the athlete's requirements, and present an optimized protein consumption plan on the 'Recommended Protein Intake' timeline. For information, to optimize protein synthesis for repair and adaptation, protein consumption is recommended at 15 – 20g every 3 – 5 hours (Thomas, et al., 2016).

CURRENT EXERCISE SCHEDULE

WAKE UP — SLEEP

CURRENT PROTEIN INTAKE

WAKE UP — SLEEP

RECOMMENDED PROTEIN INTAKE

WAKE UP — SLEEP

Figure 21 ▼

Calculation for post-exercise fluid recommendations (metric)

REHYDRATE – FLUIDS

Athlete's bodies are approximately 60 – 70% water. Large volumes of body water can be lost as athletes sweat during exercise. Body water losses equivalent to, or more than, 2% of an athlete's pre-exercise body mass can have detrimental effects on both health and performance. This is known as hypohydration, commonly referred to as dehydration. Dehydration has been shown to affect both mental, and physical performance, whilst contributing to fatigue. Thus, it is important for athletes to rehydrate post-exercise. This helps replace fluid and electrolytes lost in sweat, and reduces the risk of starting the next bout of exercise in a dehydrated state, which can impair performance (Sawka, et al., 2015).

Post-exercise, athletes should aim to drink fluid equivalent to 120% - 150% of body mass lost during exercise (i.e. 1.2 – 1.5L of fluid per kg lost during exercise) (Shirreffs & Sawka, 2011). Figures 21 and 22 provides calculations that can be used to work out post-exercise fluid requirements in metric and imperial measures respectively. A change in body mass of 1kg is the equivalent of 1 litre of fluid loss (a change of 1lb is equivalent to 16 fl oz of fluid loss). Measurement conversion tables can be found in the Appendix (Pages 75 - 77).

FLUID:

Body mass loss = Pre-exercise body mass ________kg – Post-exercise body mass ________kg = [ ] kg

FLUID NEEDS:

__________ kg body mass lost * 1.2 = [ ] L TO __________ kg body mass lost * 1.5 = [ ] L

FLUID:

Body mass loss = Pre-exercise body mass ________ lb – Post-exercise body mass ________ lb = [ ] lb

FLUID NEEDS:

__________ lb body mass lost * 20 = [ ] fl oz TO __________ lb body mass lost * 24 = [ ] fl oz

In addition, beverages containing sodium (~20 to 50mmol/L) enhance beverage palatability and stimulate thirst, whilst supporting rehydration due to sodium's impact on fluid retention and plasma volume restoration (Heaton, et al., 2017). As such, beverages containing 20 to 50 mmol sodium per litre, that are also chilled, flavoured and sweetened (factors contributing to beverage palatability and voluntary fluid intake) are recommended to support recovery from exercise (Heaton, et al., 2017). A detailed review of the fluid replacement process has been shared by Baker (2023).

For more information on hydration, including tools to support the monitoring of an athlete's hydration status, see the 'Hydration' section of the GSSI Sports Nutrition Toolkit.

Figure 22 ▲

Calculation for post-exercise fluid recommendations (imperial)

ADDITIONAL NUTRIENTS

An overview of nutrients that may support physiological recovery are highlighted in Table 22 (Heaton, et al., 2017). In addition to these nutrients, it is important that athletes meet recommended daily intakes of all micronutrients. Though there may be a particular focus on the B vitamins, vitamin C, iron, magnesium, and zinc as deficiencies may lead to mental and physical fatigue (Tardy, et al., 2020). Iron is a common nutritional deficiency in athletes, especially in female athletes (McKay, et al., 2023). A guide on identification and treatment of iron deficiency can be found in the GSSI SSE Article #239 (Peeling, et al., 2023).

Anti-oxidants and nutrients that can reduce inflammation are listed in the table below. During exercise, oxidative stress and inflammation occur. However, too much oxidative stress and inflammation may impair recovery. As such, using nutrients strategically to reduce oxidative stress and inflammation may be beneficial. Conversely, high doses of antioxidants can blunt adaptations (Baar, 2014). Thus, chronic high, or poorly timed, antioxidant supplementation is not recommended.

Monitoring athletes' nutritional status, and/or intake can be helpful to understand if the diet needs to be modified, or supplements provided, to aid the recovery process. The GSSI Sports Nutrition Toolkit provides guidance on the use of dietary analysis methods. Pages 25 - 29 of this Toolkit provide guidance on the analysis of bloods; processes which can be adapted to monitor different nutritional biomarkers to assess athletes' nutritional status. Blood based, nutritional biomarkers can be compared to reference ranges found in the literature (e.g. Peeling, et al. (2023)).

Whilst a food first approach to recovery is preferential, it is acknowledged that supplementation may be useful in particular circumstances. Further details on supplement use, including decision trees to help identify appropriate supplements, can be found in the 'Dietary Supplements' section of the GSSI Sports Nutrition Toolkit. Blackhouse, 2023, provides advice to reduce the risk of inadvertent anti-doping rule violations from supplement use.

NUTRIENT	DOSAGE	BEST SOURCES	BENEFITS	STRENGTH OF EVIDENCE*
Creatine Monohydrate	20 g/day for 5 days followed by 3–5 g/day to increase and maintain elevated muscle creatine. OR 3–5 g/day for about 30 days to increase muscle creatine	Meat, poultry, fish	Support training adaptations and recovery via increased expression of growth factors, reduced inflammation, and enhanced glycogen resynthesis	Good
n-3 PUFA	~3 g/day of EPA/DHA	Cold water fatty fish (tuna, salmon), fish oils, krill oil	Reduce inflammation Support immune function Support muscle repair and remodelling when protein intake is insufficient	Fair
Vitamin D	RDA (adults) 600 IU/day. Vitamin D status (blood 25OHD) 20–50 ng/L	Sunlight, supplements, fortified foods, fatty fish, egg yolk	Support muscle repair and recovery	Fair
Antioxidants	Individual antioxidant supplementation is not recommended. Aim to consume a balanced diet containing a variety of fruits and vegetables	Whole fruits and vegetables and 100% fruit and vegetable juices. Montgomery cherry juice, or concentrate providing 600 mg polyphenols (Botwell, et al., 2019)	Reduce inflammation	Fair
Gelatine/collagen + vitamin C	≥15 g of collagen hydrolysate with ≥50 mg of vitamin C delivered 1 h before training	Gelatin, vitamin C-rich foods (e.g., oranges, raspberries, grapefruit), dietary supplements	Promote collagen synthesis	Fair
Curcumin	Dose dependent on bioavailability 0.4–5 g/day	Turmeric, dietary supplement	Reduce inflammation	Limited
Bromelain	900–1000 mg/day	Pineapple, dietary supplements	Reduce inflammation	Limited

Table 22

Micronutrients and supplements dosage, sources, and benefits. Adapted from Heaton et al. (2017). DHA = docosahexaenoic acid, EPA = eicosapentaenoic acid, n-3 PUFA = omega-3 polyunsaturated fatty acids, RDA = recommended dietary allowance, 25OHD = 25-hydroxyvitamin D.
***Strength of evidence conclusion statements are assigned a grade by the authors based on the systematic analysis and evaluation of the supporting research evidence. Grade I = good; grade II = fair; grade III = limited; grade IV = expert opinion only; and grade V = not assignable (because there is no evidence to support or refute the conclusion). See grade definitions at http://www.andevidencelibrary.com/**

Figure 23

Examples of recovery meals

RECOVERY FOODS AND BEVERAGES

This section provides examples of recovery meals and suggestions on how to build a recovery smoothie (Figures 23 and 24 respectively)

PASTA WITH SAUCE

Carbohydrate: Pasta

Protein: Meat in the sauce e.g., beef mince or chicken

RICE/NOODLE BASED STIR FRY

Carbohydrate: Rice/noodles

Protein: Meat, tofu or fish in the stir fry

JACKET POTATOES WITH FILLING

Carbohydrate: Potato

Protein: Filling e.g., tuna, beans, chicken

BAGEL WITH FILLING

Carbohydrate: Bread

Protein: Filling e.g., lean meat, egg, tuna

TACOS

Carbohydrate: Taco and rice (side)

Protein: Meat, fish, tofu, beans

OATMEAL

Carbohydrate: Oats and fruit

Protein: Milk and yogurt

VEGETABLE CHILLI WITH RICE

Carbohydrate: Rice

Protein: Mixed beans and pulses

RECOVERY SMOOTHIES

Mix and match the ingredients to create a smoothie which contains carbohydrate, protein and fluid to support post-exercise recovery.

PROTEIN

- Protein powder
- Milk powder
- Yoghurt

CARBOHYDRATE

- Fruits: Banana, apple, mango, pineapple, orange, strawberry, cherries, blueberries
- Honey
- Frozen fruit
- Dried fruits

FLUID BASE

- Water
- Fruit juices (adds carbohydrate)
- Milk (adds protein)
- Soy milk (adds protein)
- Almond milk
- Oat milk

Figure 24

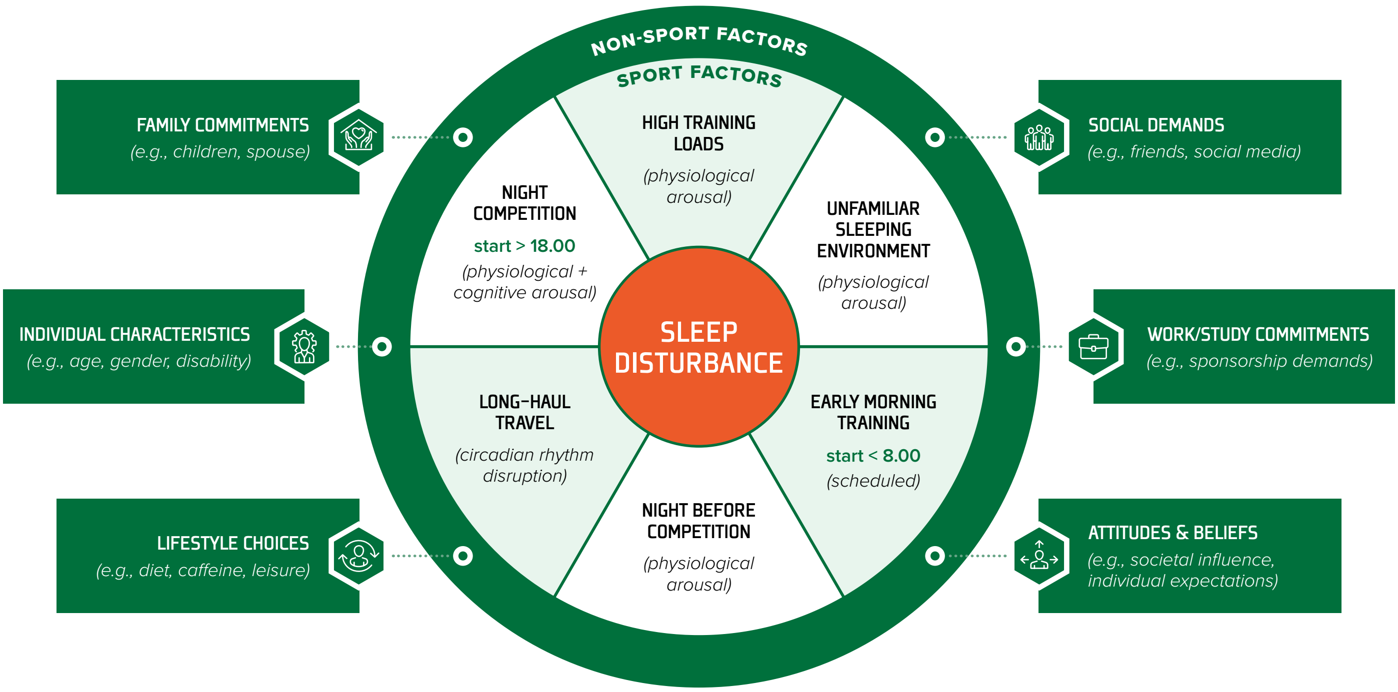
Example of how to build a recovery smoothie

Figure 25

Examples of contributory factors for sleep disturbance in athletes. Adapted from Walsh, et al., (2020).

SLEEP

Sleep is an essential element of the recovery process, allowing athletes to recover from the mental and physical demands of sport (Halson, 2014; Kölling, et al., 2019; Lambing & Bender, 2023). Inadequate sleep can lead to mood disturbances and impaired performance, decision-making ability, learning and cognition and immune function (Halson, 2016). However, there are many challenges with sleep in athletes. Some of these are highlighted in Figure 25.



Athletes require 7 – 9 hours of sleep per night (Hirshkowitz, et al., 2015). However, a one-size-fits-all approach for sleep recommendations is not ideal; instead, an individualised approach is recommended given the impact of training load and competition stress on sleep (Walsh, et al., 2020).

To improve sleep quantity and quality in athletes, a number of practical actions can be considered. Figure 26 highlights the top five practical recommendations to improve sleep in athletes. Table 23 provides a checklist of actions that can help to guide conversations with athletes, and allows sleep strategies to be developed/reviewed.

Figure 26

Top five practical recommendations to improve sleep in athletes. Adapted from Lambing & Bender (2023).

CONSIDERATION FOR A GOOD NIGHT'S SLEEP	YES/NO*	COMMENTS
Can training load be reduced? *(If relevant and feasible)*		
Can early morning training sessions be avoided? *(If relevant and feasible)*		
Has the athlete been provided with education on sleep? *(Including quantity, quality, timing, and sleep preparation; frequent check-ins are suggested to reinforce benefits of sleep)*		
Has feedback been provided to the athlete in regard to their own sleep? *(Feedback should be individual, and provided in a simple, easy to read/comprehensive format, focusing on practical recommendations on how to improve sleep, to help reduce anxiety and thus subsequent sleep disturbances)*		
Is the athlete's bedroom cool? *(Temperatures between 16°C and 20°C or 60°F to 68°F)*		
Is the athlete's bedroom dark?		
Are additional sources of light (e.g. lamps, lights on TV screens) covered?		
Is external light blocked from coming through the athlete's window when in bed? *(e.g., through the use of blackout curtains)*		
Does the athlete use an eye mask? *(Also helpful when travelling)*		
Is the athlete's bedroom quiet?		
Does the athlete use earplugs? *(Also helpful when travelling)*		
Does the athlete have a pre-sleep routine that promotes relaxation? *(e.g., reading a hard copy of a book, creating to-do lists to help with racing thoughts, and no use of electronic devices)*		

Does the athlete take a warm bath or shower before bed?		
Does the athlete engage in stretching and deep breathing before bed?		
Does the athlete go to bed at the same time each night? *(Where possible)*		
Does the athlete wake up at the same time each morning? *(Where possible)*		
Does the athlete avoid evening exposure to bright / blue light? *(e.g. watching television / using their phone / computer in bed)*		
If it is not possible to avoid evening light, is the athlete using blue-light blocking glasses or screen covers to limit exposure?		
Does the athlete avoid caffeine 4 – 5 hours prior to sleep? *(Times may vary between individuals)*		
Does the athlete consume limited fluid pre-bed, avoiding the need to use the bathroom in the night?		
If the athlete naps, are naps between 20 and 90 minutes, and away from the bedtime period, i.e. early afternoon / before 7pm? *(Note naps longer than 30 minutes may lead to sleep inertia which may result in athletes taking ~30 minutes to recover post-nap)*		
If the athlete has an important event coming up, or knows they will face periods of sleep deprivation, can they 'bank' sleep in advance?		
Has the athlete's diet be optimised to support sleep? *(If answering 'No' – See 'Nutrition for Sleep' section on page 56)*		
Does the athlete have a strategy to help cope with Jet lag when travelling? *(If answering 'No' – See 'Travel and Sleep' section on page 56)*		

Table 23

Checklist of actions to support the development / review of sleep strategies with athletes (Halson, 2013; Kölling, et al., 2019; Halson, 2019; Walsh, et al., 2020; Lambing & Bender, 2023; Bender & Lambing, 2023). *Answering questions with a 'Yes' indicates that appropriate considerations to support sleep have been accounted for. Not all answers need to be 'Yes', but any questions answered 'No' may provide opportunities to adapt sleep strategies to improve sleep.

NUTRITION FOR SLEEP

Good nutrition cannot replace a good night's sleep. However, nutritional interventions may be helpful to influence sleep (Halson, 2014). A list of practical recommendations to support sleep, through nutrition, can be found in Table 24. It is important to note that evidence to substantiate these recommendations are minimal, and inconclusive. For additional guidance on supporting an athlete with changes to their diet, see the GSSI Sports Nutrition Toolkit.

PRACTICAL RECOMMENDATIONS				
High GI foods such as white rice, pasta, bread, and potatoes may promote sleep; however, they should be consumed > 1 h before bedtime.	Diets high in carbohydrate may result in shorter sleep latencies (time taken to fall asleep).	Small doses of tryptophan (1 g) may improve both sleep latency and sleep quality. This is the equivalent of approximately 300 g of turkey or 200 g of pumpkin seeds.	Diets high in fat may negatively influence total sleep time.	Magnesium may also play a role in sleep, with supplementation benefiting symptoms of insomnia.
Alcohol can disturb both sleep quantity, and quality.	Caffeine can impact sleep by increasing sleep latency and reducing sleep efficiency and duration. Sources of caffeine include, but are not limited to, coffee, tea, caffeinated sodas and chocolate.	Diets high in protein may result in improved sleep quality.	The hormone melatonin, and foods that have a high melatonin concentration, may decrease sleep onset time. Tart cherry juice can impact melatonin secretion.	When total caloric intake is decreased, sleep quality may be disturbed.

TRAVEL AND SLEEP

Training and competing often require both short and long term travel. This can result in travel fatigue. If travels result in jet lag, there may also be disturbances to the body's 24-hour circadian rhythm which prepares the body for night time sleeping and waking up in the morning. Both travel fatigue and jet lag may impact subsequent performance and recovery (Kölling, et al., 2018; Walsh et al., 2020; Janse van Rensburg, et al., 2021). A review and consensus statement on monitoring travel fatigue and jet lag in athletes (Janse van Rensburg, et al., 2021) provides detailed information to help manage and prevent/reduce the effect of travel fatigue and jet lag.

TRAINING ADJUSTMENT AND REST

Training provides the body with a repeated stimulus, to which it can adapt over time to improve exercise capacity and performance (Hargreaves & Hawley, 2003). Allowing athletes to experience a level of stress, causing fatigue, overload, and/or overreaching, followed by a period of rest, is essential to drive adaptation, therefore enhance performance over time (Meeusen, et al., 2013; Thorpe, 2021). In addition, training allows athletes time to learn and master new moves, skills, and/or tactics in preparation for competition.

Exercise demands will depend on the goals of the individual training sessions, and the demands of competition within a period of time. That is, exercise demands may be high in pre-season to promote adaptations, and high during congested fixture periods, but might be lower during periods of tactical training sessions.

A build-up of intensified training, without adequate recovery may result in non-functional overreaching, and/or prolonged decrements in performance, and symptoms of maladaptation, as well as an increase in perceived mental and physical fatigue (Meeusen, et al., 2013; Kellmann, et al., 2018). In turn, this can also result in sleep disturbances, which is known to further impact both recovery and performance (Walsh, et al., 2020). As such, it is important for athletes to balance stress (from exercise and life demands, and the resultant fatigue)

Table 24 ▲

Potential practical recommendations to support sleep quality and quantity (Vella, et al., 2010; Halson., 2014; Lambing, et al., 2022).

with recovery to support adaptations and performance (Kellmann, et al., 2018). Training load can be adjusted to help balance stress and fatigue proactively, or reactively in response to athlete monitoring.

Adequate rest is one of the simplest methods to reduce stress and fatigue from training, and/or manage symptoms. It is suggested that athletes have at least one day of passive rest per week, especially during periods of intensified training. Rest days may also allow distractions from competition, and thus reduced psychological stress (Meeusen, et al., 2013).

In addition to rest, training load should be individualised (increased or decreased) to manage fatigue depending on the specific athlete's response to training (Budgett, 1998; Meeusen, et al., 2012). In team sport environments, training load (volume, intensity, or frequency), can be adjusted regularly (periodised) depending on the phase of the training cycle and demands of competition (Halson, 2014).

Return to play strategies for athletes who have had a period of time off as a result of inadequate recovery should be individualised on the basis of signs and symptoms, given there is no definitive indicator of recovery (Meeusen, et al., 2013).

PSYCHOLOGICAL RECOVERY

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 as well as mood changes. Mental fatigue can reduce physical capacity, assessed through reduced time to exhaustion and elevated rating of perceived exertion (RPE) and has been shown to fluctuate throughout a competitive season (Van Cutsem, et al., 2017; Russell, et al., 2021).

Rest and breaks from training can also provide additional opportunities for psychological recovery. This recovery may be proactive, and may help athletes increase their capacity to cope with the stresses of training and competition (Driller & Leabeater, 2023). These recovery strategies are typically determined by the individual athlete, to suit their individual needs, but should be encouraged by members of the sports performance team. Examples of such strategies are listed in Figure 27. Further research is required to understand best-practice management strategies (Russell, et al., 2023). The sports psychologist within the performance team can be consulted to help support psychological recovery.

Figure 27

Examples of strategies to support psychological recovery (Kenttä & Hassmén, 1998; Loch, et al., 2019; Driller & Leabeater, 2023; Russell, et al., 2023).

GATORADE SPORTS SCIENCE INSTITUTE™

ADDITIONAL MODALITIES

Nutrition, sleep, training adjustment and rest, form the foundations and centre of the recovery pyramid (Figure 19). At the top of the pyramid, sits additional recovery modalities. These may be considered to help support athletes' recovery once best practices for nutrition, sleep, and training adjustment and rest have been implemented. These additional modalities include different forms of water immersion, compression, massage and more.

This section of the toolkit aims to provide an overview of the latest science, covering common recovery modalities, and acts as a guide, rather than specific recommendations. It is out of scope to provide a full review of all recovery modalities, though reviews can be found elsewhere (Halson, 2013; Driller & Leabeater, 2023). In some cases, combinations of recovery modalities may be better than the use of single recovery modalities, though it is not in the scope of this toolkit to review potential combinations.

Pages 59 - 65 provide infographics with overviews of potential protocols, mechanisms and benefits of common recovery modalities. Much is unknown about many of the recovery modalities, thus more research is required to confirm the details shared. In addition, more research is required to understand chronic use of these recovery modalities, and their potential effect on physiological adaptations (Driller & Leabeater, 2023). However, this is not discussed in this Toolkit.

When reviewing the following pages, it is important to consider that there are variations in physiological and psychological stressors that occur during exercise. These variations may occur for a number of different reasons, including the mode of exercise, and level of training. In addition, recovery modalities may impact individuals in different ways. For example, some recovery modalities may impact well-trained athletes to a different level, compared to individuals who have less training. As such, there is no one-size-fits-all approach to recovery.

Information gained from the athlete monitoring process can first be reviewed, in combination with knowledge of cause(s) of fatigue, to understand the specific recovery needs of athletes. For example, do athletes need to recover from muscle soreness, or something else? Once this has been established, the infographics on the following pages can be used as a starting point, to help identify suitable recovery modalities. From here, the literature can be reviewed specific to an athlete's sport, or mode of fatigue. This is because each recovery modality may have different protocols, suitable for different sports, depending on the mode of fatigue. As an example, Basketball specific recovery modalities can be found in the GSSI Basketball Nutrition book. The information on the following pages should be reviewed alongside considerations in Table 15, to help build a recovery strategy.

Wilcock, et al., 2006; Versey, et al., 2013; Stephens, et al., 2017; Tipton, et al., 2017; Dupuy, et al., 2018; Davis, et al., 2022; Moore, et al., 2022; Moore, et al., 2023

COLD WATER IMMERSION (CWI)

POTENTIAL PROTOCOL

Temp
10°C to 15°C

Duration
5 to 15 mins

Depth
Unknown. Typically whole body minus head and neck. Minimum depth likely waist height.

Passive or Active
Unknown. Typically passive.

Timing
Proximity to exercise unknown. Typically within 30 minutes post-exercise or the following day.

POTENTIAL MECHANISMS

Cold water immersion may impact recovery due to the effects of hydrostatic pressure and cold water, which may:

- Impact cardiac output, peripheral resistance and blood flow
- Lower skin, muscle and core temperature
- Reduce nerve conduction velocity
- Provide an analgesic effect

Which in turn, may help:

- Reduce inflammation
- Reduce formation of oedema
- Reduce secondary muscle damage
- Reduce muscle spasm
- Reduce feelings of pain

POTENTIAL BENEFITS

- Reduced perception of muscle soreness
- Increased perception of recovery
- Reduced perception of fatigue
- Recovery of power performance

PRACTICAL TIPS / ADVICE

If passive, could combine with recovery nutrition practices.

Could combine with active recovery, if practical.

Athletes / practitioners could create their own CWI where other means are not available. For example, adding 10 – 20lb (5 – 10kg) bags of ice to hotel baths / inflatable tubs.

Targeted cooling may be an alternative option (e.g. application of an ice pack or cooling devices).

Water immersion alone (independent of temperature) may support recovery due to the impact of hydrostatic pressure, and may be an alternative when CWI is not appropriate.

Athletes should be supervised at all times when immersed in water.

CONTRAST WATER THERAPY (CWT)

POTENTIAL PROTOCOL

Temp
10°C to 15°C and ~36°C to 38°C
Unknown if CWT should end with HWI or CWI.

Duration
Alternating 1 minute immersions / showers, for up to 15 minutes.

Depth
Unknown. Studies reporting benefits typically immerse whole body minus head and neck.

Passive or Active
Unknown.

Timing
Proximity to exercise unknown.

POTENTIAL MECHANISMS

Contrast water therapy may result in:

- Vascular pumping / squeezing (vaso-pumping). This is alternating vasoconstriction and vasodilation, as a result of differing temperatures
- Increased blood flow

Which in turn, may help:

- Increase clearance of metabolic waste
- Reduce inflammation
- Reduce formation of oedema
- Reduce muscle spasm
- Reduce stiffness and pain
- Increase range of motion

POTENTIAL BENEFITS

- Reduced perception of muscle soreness
- Recovery of strength performance
- Recovery of power performance

PRACTICAL TIPS / ADVICE

If passive, could combine with recovery nutrition, e.g. shakes. Though this may be more challenging as a result of movement between hot and cold pools / showers.

CWT may be a time effective recovery modality for larger teams, with athletes split between hot and cold pools

Athletes should be supervised at all times when immersed in water.

Myrer, 1994; Wilcock, et al., 2006; Bieuzen, et al., 2013; Versey, et al., 2013; Juliff, et al., 2014; Dupuy, et al., 2018

Banfi, et al., 2010; Dupuy, et al., 2018; Lombardi, et al., 2017; Rose, et al., 2017; Bouzigon, et al., 2021

WHOLE-BODY CRYOTHERAPY

POTENTIAL PROTOCOL

Temp
-110°C to -140°C

Duration
60 seconds at -60°C followed by two to three minutes at -110°C to -140°C.

Timing
Immediately post-exercise and in the two to three days post-exercise.

POTENTIAL MECHANISMS

Whole-body cryotherapy may:

- Induce peripheral vasoconstriction
- Stimulate autonomic nervous parasympathetic system and increase noradrenaline
- Increase muscle oxygenation
- Provide an analgesic effect

Which in turn, may help:

- Reduce inflammation
- Reduce secondary muscle damage
- Reduce feelings of pain

POTENTIAL BENEFITS

Evidence on the efficacy of whole-body cryotherapy is inconsistent. Some of the evidence suggests potential benefits for:

- Reduced perception of muscle soreness
- Reduced perception of pain

PRACTICAL TIPS / ADVICE

Athletes should be dry, and wearing minimal/safety clothing (i.e. bathing suits, shoes/socks, masks, gloves and or hats) when inside a cryotherapy chamber.

Should only be used in the presence of a trained professional.

Athletes with differing body fat percentages may respond differently to the treatment.

Cryotherapy may help with sleep, however more research is required.

ACTIVE RECOVERY

POTENTIAL PROTOCOL

Type/Intensity
Low to moderate intensity, aerobic exercise. Should not result in substantial additional fatigue.

Target muscle
Likely beneficial to incorporate the same muscles that have been fatigued / damaged.

Duration
Unknown, however 6 – 10 minutes has shown benefits.

Timing
Proximity to exercise unknown. Typically within 1 hour post-exercise.

POTENTIAL MECHANISMS

Active recovery may:

- Increase blood flow to exercised area
- Increase oxygen delivery and oxidation to exercised area
- Decrease blood pooling in the limbs
- Help restore heart rate to normal activity

Which in turn, may help:

- Increase clearance of lactate from blood*
- Increase clearance of additional metabolic waste

**The practical relevance of blood lactate clearance in recovery is questionable*

POTENTIAL BENEFITS

Evidence on the efficacy of active recovery is inconsistent, with the majority of the evidence suggesting no effect on recovery of performance. However, active recovery may support:

- Reduced perception of muscle soreness
- Increased perception of recovery

PRACTICAL TIPS / ADVICE

Could combine with mobility sessions.

Active recovery may be used to support relaxation, and provide opportunities to socialise and reflect on training or competition.

Halson, 2014; Mika, et al., 2016; Dupuy, et al., 2018; van Hooren & Peake, 2018; Ortiz Jr, et al., 2019

Weerapong, et al., 2005; Halson, 2014; Poppendieck, et al., 2016; Dupuy, et al., 2018

MASSAGE

POTENTIAL PROTOCOL

Duration
Unknown. 5 – 12 minutes may be helpful for short-term recovery.

Massage Type
Unknown. Typically targets fatigued muscle.

Timing
Proximity to exercise is unknown. Massage immediately post exercise has shown benefits.

POTENTIAL MECHANISMS

Massage may:

- Decrease tissue adhesion
- Increase muscle compliance
- Increase blood flow
- Alter release of hormones
- Reduce muscle tension

Which in turn, may help:

- Decrease muscle-tendon stiffness
- Increase range of motion
- Reduce pain
- Increase relaxation
- Reduce inflammation
- Reduce swelling and muscle spasm

POTENTIAL BENEFITS

To date, evidence does not suggest massage supports recovery of performance. However, some benefits of massage may include:

- Reduced perception of muscle soreness
- Reduced perception of fatigue

PRACTICAL TIPS / ADVICE

May support relaxation, and could be used in combination with other methods to support psychological recovery e.g. listening to music, or mindfulness.

MYOFASCIAL RELEASE
(E.G. FOAM ROLLING, MASSAGE BALLS)

POTENTIAL PROTOCOL

Duration
90 - 120 seconds per muscle group. Less than 45 seconds appears to be inadequate.

Type of roller
Unknown.

Amount of force
Bodyweight, or up to 50% of maximum discomfort.

Timing
Proximity to exercise is unknown.

POTENTIAL MECHANISMS

Myofascial release involves direct and sweeping pressure on soft tissue, which may:

- Increase blood flow
- Reduce arterial stiffness
- Reduce muscle tension
- Effect pain-modulating mechanisms such as the diffuse noxious inhibitory control

Which in turn, may help:

- Increase clearance of metabolic waste
- Reduce formation of oedema
- Reduce inflammation
- Improve tissue repair
- Increase range of movement
- Support an analgesic effect

POTENTIAL BENEFITS

- Reduced perception of muscle soreness
- Reduced perception of pain
- Recovery of sprint performance
- Recovery of strength performance

PRACTICAL TIPS / ADVICE

Can be easily added into daily routine.

Not time intensive.

Massage devices can easily be transported when travelling.

Could be used in combination with other methods to support psychological recovery, e.g. listening to music.

Hughes & Ramer, 2019; Wiewelhove, et al., 2019; Hendricks, et al., 2020; Ferreira, et al., 2022

Watanuki & Murata, 1994; Kraemer, et al., 2001; Halson, 2014; Brown, et al., 2017; Dupuy, et al., 2018; Hill, et al., 2017; Davis, et al., 2022; Weakley, et al., 2022

COMPRESSION GARMENTS

POTENTIAL PROTOCOL

Garment pressure
Likely ≥14 - 15mmHg, with graded compression to the limbs from proximal to distal.

Target area
Entire limb which has been used in prior exercise.

Duration
As long as comfortable, but should not let garments compromise sleep.

Timing
Proximity to exercise is unknown. Likely as soon as possible post-exercise.

POTENTIAL MECHANISMS

Mechanical pressure from the use of compression garments may:

- Increase blood flow
- Enhance venous return
- Reduce intramuscular space available for swelling

Which in turn, may help:

- Reduce swelling / formation of oedema
- Reduce delivery time of oxygen and nutrients to working muscles
- Increase clearance of metabolic waste

POTENTIAL BENEFITS

The majority of evidence suggests that compression garments have no impact on recovery of performance. However, there may be benefits for:

- Reduced perception of muscle soreness
- Reduced perception of muscle pain
- Reduced perception of fatigue

PRACTICAL TIPS / ADVICE

May be a helpful passive recovery modality for use when travelling post-training/competition, especially on long-haul flights.

Could be used in combination with other methods to support psychological recovery e.g. listening to music, or mindfulness.

STRETCHING

POTENTIAL PROTOCOL

Type of movement
Dynamic and pain free, and should not elicit discomfort and pain.

Duration
≥ 60 seconds per muscle group.

Timing
Proximity to exercise is unknown.

POTENTIAL MECHANISMS

Stretching may:

- Increase 'stretch tolerance'
- Reduce tendon and muscle stiffness

Which in turn, may help:

- Improve range of movement

POTENTIAL BENEFITS

Whilst some individual studies have reported positive benefits of post-exercise stretching, to date, several reviews have concluded that there is not sufficient evidence to conclude benefits for performance or reduced perception of muscle soreness.

PRACTICAL TIPS / ADVICE

Suggest focusing on areas that are tight, but not painful.

Taking time to stretch also allows time for mindfulness and breathing exercising to facilitate mental recovery.

Easy to adopt and not dependent on equipment.

Sands, et al., 2013; Halson, 2014; Dupuy, et al., 2018; American College of Sports Medicine, 2018; van Hooren & Peake, 2018; Afonso, et al., 2021

SIGNIFICANTLY MORE RESEARCH IS REQUIRED

The recovery modalities discussed next require significantly more research. Literature on these modalities is limited, with few meta-analyses or systematic reviews completed (Driller & Leabeater, 2023). The information provided should be reviewed with caution, given the limited literature to date.

There is very little data in athletes to support the use of saunas on recovery, and the available data suggests their use could impair factors of recovery, thus it has not been discussed here, though there may be potential to support relaxation (Driller & Leabeater, 2023).

HOT WATER IMMERSION (HWI)

POTENTIAL PROTOCOL

Temp	Duration	Depth	Passive or Active	Timing
Approximately 36°C to 38°C	Unknown. Studies reporting benefits have ranged from 14 – 24 minutes.	Unknown. Typically whole body minus head and neck.	Unknown. Typically passive.	Proximity to exercise unknown, but avoid using if body temperature is elevated.

POTENTIAL MECHANISMS

Hot water immersion may result in:

- Vasodilation
- Increased blood flow
- Increased skin, muscle and core temperature
- Eased muscle tension

Which in turn, may help:

- Reduce delivery time of oxygen and nutrients to working muscles
- Increase clearance of metabolic waste

POTENTIAL BENEFITS

Few studies have investigated the use of HWI on recovery to date, with inconsistent results. Whilst significantly more evidence is required, some of the evidence suggests potential for the following benefits:

- Recovery of jump power performance*
- Recovery of isometric squat force

**In combination with underwater jet-massage*

PRACTICAL TIPS / ADVICE

If passive, could combine with recovery nutrition practices – Ensure provision of sufficient fluid, given the higher temperatures.

A warm bath can aid relaxation, and before bed can aid sleep.

Water immersion alone (independent of temperature) may support recovery due to the impact of hydrostatic pressure, and may be an alternative when CWI is not appropriate.

Athletes should be supervised at all times when immersed in water.

▲ Viitasalo, et al., 1995; Kuligowski, et al., 1998; Wilcock, et al., 2006; Valie, et al., 2008; Versey, et al., 2013; McGorm, et al., 2018; Davis, et al., 2022; Jackman, et al., 2023

Cranston & Driller, 2022; Heapy, et al., 2018; Blumkaitis, et al., 2022

INTERMITTENT PNEUMATIC COMPRESSION (IPC)
(E.G. COMPRESSION BOOTS)

POTENTIAL PROTOCOL

Pressure
Unknown. Of studies reporting benefits, typically 80 – 110 mmHg is used.

Duration
Unknown. Of studies reporting benefits, typically 20 – 30 minutes.

Timing
Proximity to exercise unknown.

POTENTIAL MECHANISMS

Intermittent pneumatic compression may:

- Reduce area available for swelling
- Increase venous and lymphatic return
- Increase blood flow

Which in turn, may help:

- Formation of oedema

POTENTIAL BENEFITS

Few studies have investigated the use of IPC on recovery to date, with inconsistent results. Whilst significantly more evidence is required, some of the evidence suggests potential for the following benefits:

- Reduced perception of muscle soreness
- Reduced muscle fatigue
- Recovery of jump performance

PRACTICAL TIPS / ADVICE

Could be used in combination with other methods to support psychological recovery e.g. listening to music, or mindfulness.

PERCUSSIVE THERAPY
(E.G. MASSAGE GUNS)

POTENTIAL PROTOCOL

There is limited research to discuss potential protocols for the use of percussive therapy.

POTENTIAL MECHANISMS

The delivery of pressure/vibration/massage from Percussive Therapy may:

- Promote blood flow
- Reduce myofascial restriction and tension
- Break up myofascial trigger points

Which in turn, may help:

- Increase range of motion
- Alleviate pain

POTENTIAL BENEFITS

Few studies have investigated the use of percussive therapy for recovery to date, with inconsistent results. Whilst significantly more evidence is required, some of the evidence suggests potential for the following benefits:

- Reduced muscle stiffness
- Recovery of maximal voluntary contractions

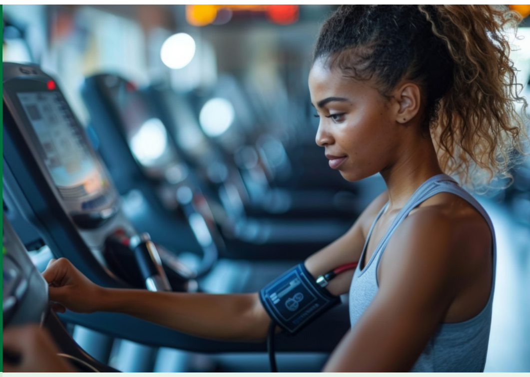
PRACTICAL TIPS / ADVICE

Athletes should seek advice from qualified professionals before incorporating into a recovery program.

García-Sillero, et al., 2021; Wang, et al., 2022; Ferreira, et al., 2023

Beaven, et al., 2012; Page, et al., 2017; Arriel, et al., 2018; Daab, et al., 2021; Ceylan, et al., 2023; Oliva-Lozano, et al., 2024

BLOOD FLOW RESTRICTION (BFR)



POTENTIAL PROTOCOL

There is limited research to discuss potential protocols for the use of blood flow restriction. Studies with potential benefits have used a variety of different protocols.

POTENTIAL MECHANISMS

BFR restricts arterial inflow and venous outflow (occlusion), before reperfusion which together may result in:

- Hypoxia in the muscle tissue
- Increased blood flow
- Elevated levels of adenosine and nitric oxide
- Vasodilation

Which in turn, may help:

- Reduce muscle damage
- Reduce muscle soreness

POTENTIAL BENEFITS

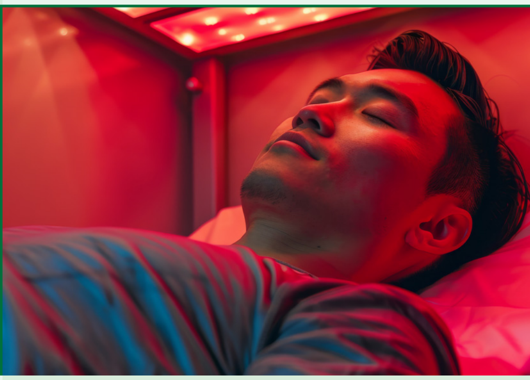
Few studies have investigated the use of BFR on recovery to date, with inconsistent results. Whilst significantly more evidence is required, some of the evidence suggests potential for the following benefits:

- Reduced perception of muscle soreness
- Recovery of jump performance
- Recovery of sprint performance
- Recovery of cycling performance (time to exhaustion)
- Recovery of maximal voluntary contractions

PRACTICAL TIPS / ADVICE

Athletes should seek advice from qualified professionals before incorporating into a recovery program.

FAR INFRARED (FIR) RADIATION



POTENTIAL PROTOCOL

There is limited research to discuss potential protocols for the use of far infrared radiation. Studies with potential benefits have used a variety of different devices and protocols.

POTENTIAL MECHANISMS

Far Infrared Radiation may:

- Be perceived by the body as radiant heat and absorbed by the body
- Have anti-inflammatory effects
- Help rejuvenate muscle-tendon unit issues
- Promote cerebral blood flow and enhance blood circulation

Which in turn, may help:

- Delay the appearance of muscle fatigue

However, these potential mechanisms are based off in vitro and animal studies

POTENTIAL BENEFITS

Few studies have investigated the use of FIR on recovery to date, with inconsistent results. Whilst significantly more evidence is required, some of the evidence suggests potential for the following benefits:

- Reduced perception of muscle soreness
- Recovery of jump performance
- Recovery of maximal voluntary contractions

PRACTICAL TIPS / ADVICE

No known interaction with Nutrition.

Mero, et al., 2015; Bontemps, et al., 2021; Hsieh, et al., 2022; Chen, et al., 2023)

REFERENCES

Afonso, J. et al., 2021. The Effectiveness of Post-exercise Stretching in Short-Term and Delayed Recovery of Strength, Range of Motion and Delayed Onset Muscle Soreness: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Front Physiol, 5(12).

Altini, M., 2024. Making sense of wearables. GSSI Sports Science Exhange, 37(250), pp. 1-6.

Altini, M. & Plews, D., 2021. What is behind changes in resting heart rate and heart rate variability? A large-scale analysis of longitudinal measurements acquired in free-living. Sensors (Basel), 21(23), p. 7932.

Alzaid, F., Patel, V. B. & Preedy, V. R., 2015. Biomarkers of oxidative stress in blood. In: General methods in biomarker research and their applications. s.l.:Springer, pp. 567-594.

American College of Sports Medicine, 2018. ACSM's Guidelines for Exercise Testing and Prescription. 10th ed. Philadelphia: Lippincott Williams & Wilkins.

Aristidis, A., Vasilis, K. & Sotirois, K., 2013. Salivary alpha-amylase and salivary flow rate in young adults. Open Dent J, Volume 7, pp. 7-15.

Arriel, R. A., de Souza, H. L., da Mota, G. R. & Marocolo, M., 2018. Declines in exercise performance are prevented 24 hours after post-exercise ischemic conditioning in amateur cyclists. PLoS One, 13(11).

Baar, K., 2014. Nutrition and the adaptation to endurance training. Sports Med, 44(Suppl 1), pp. 5-12.

Baar, K., 2016. Recovery nutrition for the basketball athlete. GSSI Sports Science Exchange, 29(199), pp. 1-4.

Baar, K. & Heaton, L. E., 2015. In-season recovery nutrition for American Football. GSSI Sports Science Exchange, Issue 144.

Bagger, M., Petersen, P. H. & Pedersen, P. K., 2003. Biological variation in variables associated with exercise training. Int J Sports Med, 24(6), pp. 433-40.

Baker, L. B., 2023. The fluid replacement process: Principles of beverage formulation for athletes. GSSI Sports Science Exchange, 36(244), pp. 1-8.

Banfi, G., Lombardi, G., Colombini, A. & Melegati, G., 2010. Whole-body cryotheraphy in athletes. Sports Med, 40(6), pp. 509-17.

Banister, E. W. & Calvert, T. W., 1980. Planning for future performance: Implications for long term training. Can J Appl Sport Sci, 5(3), pp. 170-6.

Beato, M. et al., 2024. Monitoring readiness to train and perform in Female Football: Current evidence and recommendations for practitioners. Int J Sports Physiol Perform, 19(3), pp. 223-231.

Beaven, C. M. et al., 2012. Intermittent lower-limb occlusion enhances recovery after strenuous exercise. Appl Physiol Nutr Metab, 37(6), pp. 1132-9.

Bellenger, C. R. et al., 2016. Monitoring athletic training status through autonomic heart rate regulation: A systematic review and meta-analysis. Sports Med, 46(10), pp. 1461-86.

Bender, A. M. & Lambing, K. A., 2023. A practical guide to improve sleep and performance in athletes. Int J Sports Sci Coach, 19(1).

Bender, A. M., Lawson, D., Werrhner, P. & Samuels, C. H., 2018. The clinical validation of the Athlete Sleep Screening Questionnaire: an instrument to identify athletes that need further sleep assessment. Sports Med Open, 4(1), p. 23.

Bieuzen, F., Bleakley, C. M. & Costello, J. T., 2013. Contrast water therapy and exercise induced muscle damage: A systematic review and meta-analysis. PLoS One, 8(4).

Blackhouse, S. H., 2023. A behaviourally informed approach to reducing the risk of inadvertent anti-doping rule violations from supplement use. Sports Med, 53(Suppl 1), pp. 67-84.

Blumkaitis, J. C. et al., 2022. Effects of an external pneumatic compression device vs static compression garment on peripheral circulation and markers of sports performance and recovery. Eur J Appl Physiol, 122(7), pp. 1709-1722.

Bontemps, B., Gruet, M., Vercruyssen, F. & Louis, J., 2021. Utilisation of far infrared-emitting garments for optimising performance and recovery in sport: Real potential or new fad? A systematic review. PLoS One, 16(5).

Borg, G. A., 1982. Psychophysical bases of percieved exertion. Med Sci Sports Exerc, 14(5), pp. 377-81.

Borresen, J. & Lambert, M. I., 2008. Quantifying training load: A comparison of subjective and objective methods. Int J Sports Physiol Perform, 3(1), pp. 16-30.

Botwell, J. L., Wangdi, J. T. & Kelly, V. G., 2019. Fruit-derived polyphenol supplementation for performance and recovery. GSSI Sports Science Exchange, 32(195), pp. 1-5.

Bouzigon, R. et al., 2021. Cryostimulation for post-exercise recovery in athletes: A consensus and position paper. Front Sports Act Living, Volume 3.

Brown, F. et al., 2017. Compression Garments and Recovery from Exercise: A Meta-Analysis. Sports Med, 47(11), pp. 2245-2267.

Buchheit, M., 2014. Monitoring training status with HR measures: Do all roads lead to Rome?. Front Physiol, 5(73).

Budgett, R., 1998. Fatigue and underperformance in athletes: the overtraining syndrome. Br J Sports Med, 32(2), pp. 107-10.

Burd, N. A. et al., 2011. Enhanced amino acid sensitivity of myofibrillar protein synthesis persists for up to 24 h after resistance exercise in young men. J Nutr, 141(4), pp. 568-73.

Buysse, D. J. et al., 1989. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Pstchiatry Res, 28(2), pp. 193-213.

Carney, C. E. et al., 2012. The consensus sleep diary: standardizing prospective sleep self-monitoring. Sleep, 35(2), pp. 287-302.

Ceylan, B., Taşkın, H. B. & Šimenko, J., 2023. Effect of Ischemic Preconditioning on Acute Recovery in Elite Judo Athletes: A Randomized, Single-Blind, Crossover Trial. Int J Sports Physiol Perform, 18(2), pp. 180-186.

Chen, T. C. et al., 2023. Effects of far-infrared radiation lamp therapy on recovery from muscle damage induced by eccentric exercise. Eur J Sport Sci, 23(8), pp. 1638-1646.

Coutts, A. J., 2016. Fatigue in football: It's not a brainless task!. J Sports Sci, 34(14), p. 1296.

Coyle, E. F., 2000. Physical activity as a metabolic stressor. Am J Clin Nutr, 72(Suppl 1), pp. 512-20.

Cranston, A. W. & Driller, M. W., 2022. Investigating the use of an intermittent sequential pneumatic compression arm sleeve for recovery after upper-body exercise. J Strength Cond Res, 36(6), pp. 1548-1553.

Daab, W. et al., 2021. Brief cycles of lower-limb occlusion accelerate recovery kinetics in soccer players. Phys Sportsmed, 49(2), pp. 143-150.

Daanen, H. A. et al., 2012. A systematic review on heart-rate recovery to monitor changes in training status in athletes. Int J Sports Physiol Perform, 7(3), pp. 251-60.

Davis, J. K. et al., 2022. In-Season Nutrition Strategies and Recovery Modalities to Enhance Recovery for Basketball Players: A Narrative Review. Sports Med, 52(5), pp. 971-993.

Driller, M. & Leabeater, A., 2023. Fundamentals or icing on top of the cake? A narrative review of recovery strategies and devices for athletes. Sports (Basel), 11(11), p. 213.

Driller, M. W., Mah, C. D. & Halson, S. L., 2018. Development of the athlete sleep behavior questionnaire: a tool for identifying maladaptive sleep practices in elite athletes. Sleep Sci, 11(1), pp. 37-44.

Dunbar, J., Hazell, G. & Jehanli, A., 2015. Evaluation of a new Point of Care quantitative Cube reader for salivary analysis in Premier League soccer clubs.. Wallingford: International Sports Science and Sports Medicine Conference..

Dupuy, O. et al., 2018. An Evidence-Based Approach for Choosing Post-exercise Recovery Techniques to Reduce Markers of Muscle Damage, Soreness, Fatigue, and Inflammation: A Systematic Review With Meta-Analysis. Front Physiol, 9(403).

Ferreira, R. M., Martins, P. N. & Goncalves, R. S., 2022. Effects of self-myofascial release instruments on perforamnce and recovery: An umbrella review. Int J Exerc Sci, 15(3), pp. 861-883.

Ferreira, R. M. et al., 2023. The effects of massage guns on performance and recovery: A systematic review. J Funct Morphol Kinesiol, 8(3), p. 138.

Foster, C., 1998. Monitoring training in athletes with reference to overtraining syndrome. Med Sci Sports Exerc, 30(7), pp. 1164-8.

Foster, C. et al., 2001. A new approach to monitoring exercise training. J Stregth Cond Res, 15(1), pp. 109-115.

Freese, E. C., Sopeña, B. C. & Wolfe, A. S., 2023. Monitoring recovery in American Football. GSSI Sports Science Exchange, 36(245), pp. 1-8.

García-Sillero, M. et al., 2021. Comparison of interventional strategies to improve recovery after eccentric exercise-induced muscle fatigue. Int J Environ Res Public Health, 18(2), p. 647.

Grant, D. A. et al., 2017. 3-minute smartphone-based and tablet-based psychomotor vigilance tests for the assessment of reduced alertness due to sleep deprivation. Behav Res Methods, 49(3), pp. 1020-1029.

Habay, J. et al., 2021. Mental fatigue and sport-specific psychomotor performance: A systematic review. Sports Med, 51(7), pp. 1527-1548.

Haddad, H. A. et al., 2011. Reliability of resting and postexercise heart rate measures. Int J Sports Med, 32(8), pp. 598-605.

Halson, S. L., 2013. Recovery techniques for athletes. GSSI Sports Science Exchange, 26(120), pp. 1-6.

Halson, S. L., 2013. Sleep and the elite athlte. GSSI Sports Science Exchange, 26(113), pp. 1-4.

Halson, S. L., 2014. Monitoring Fatigue and Recovery. GSSI Sports Science Exchange, 27(135), pp. 1-6.

Halson, S. L., 2014. Sleep in elite athletes and nutritional interventions to enhance sleep. Sports Med, 44(Suppl 1), pp. 13-23.

Halson, S. L., 2016. Sleep and Athletes. GSSI Sports Science Exchange, 29(167), pp. 1-4.

Halson, S. L., 2019. Sleep monitoring in athletes: Motivation, methods, miscalculations and why it matters. Sports Med, 49(10), pp. 1487-1497.

Heapy, A. M. et al., 2018. A randomized controlled trial of manual therapy and pneumatic compression for recovery from prolonged running - an extended study. Res Sports Med, 26(3), pp. 354-364.

Hearris, M. A., Hammond, K. M., Fell, J. M. & Morton, J. P., 2018. Regulation of muscle glycogen metabolism during exercise: Implications for endurance performance and training adaptations. Nutrients, 10(3), p. 298.

Heaton, L. E. et al., 2017. Selected in-season nutritional strategies to enhance recovery for team sport athletes: A practical overview. Sports Med, 47(11), pp. 2201-2218.

Hendricks, S. et al., 2020. Effects of foam rolling on performance and recovery: A systematic review of the literature to guide practitioners on the use of foam rolling. J Bodyw Mov Ther, 24(2), pp. 151-174.

Hill, J. et al., 2017. Effects of Compression Garment Pressure on Recovery from Strenuous Exercise. Int J Sports Physiol Perform, 12(8), pp. 1078-1084.

Hirshkowitz, M. et al., 2015. National Sleep Foundation's sleep time duration recommendations: Methodology and results summary. Sleep Health, 1(1), pp. 40-43.

Hooper, S. L. & Mackinnon, L. T., 1995. Monitoring overtraining in athletes. Recommendations. Sports Med, 20(5), pp. 321-7.

Hsieh, C. et al., 2022. Effects of Far-Infrared Radiation-Lamp Therapy on Recovery From Simulated Soccer Match Running Activities in Elite Soccer Players. Int J Sports Physiol Perform, 17(9), pp. 1432-1438.

Hughes, G. A. & Ramer, L. M., 2019. Duration of myofascial rolling for optimal recovery, range of motion, and performance: A systematic review of the literature. Int J Sports Phys Ther, 14(6), pp. 845-859.

Jackman, J. S. et al., 2023. Effect of hot water immersion on acute physiological responses following resistance exercise. Front Physiol, 5(14).

Janse van Rensburg, D. C. et al., 2021. Managing travel fatigue and jet lag in athletes: A review and consensus statement. Sports Med, 51(10), pp. 2029-2050.

Johns, M. W., 1991. A new method for measuring daytime sleepiness: The Epworth sleepiness scale. Sleep, 14(6), pp. 540-5.

Juliff, L. E. et al., 2014. Influence of contrast shower and water immersion on recovery in elite Netball. J Strength Cond Res, 28(8), pp. 2353-2358.

Kallus, W. & Kellmann, M., 2016. The recovery-stress questionnaires: User manual. Frankfurt: Pearson.

Keaney, L. C., Kilding, A. E., Merien, F. & Dulson, D. K., 2018. The impact of sport related stressors on immunity and illness risk in team-sport athletes. J Sci Med Sport, 21(12), pp. 1192-1199.

Kellmann, M., 2002. Underrecovery and overtraining: Different concepts - similar impact?. In: Enhancing recovery: preventing underperformance in athletes. Champaign, IL: Human Kinetics, pp. 3-24.

Kellmann, M. et al., 2018. Recovery and performance in sport: Consensus statement. Int J Sports Physiol Perform, 13(2), pp. 240-245.

Kellmann, M. & Kallus, K. W., 2001. Recovery-stress questionnaire for athletes: User manual. Champaign, IL: Human Kinetics.

Kenttä, G. & Hassmén, P., 1998. Overtraining and recovery. A conceptual model. Sports Med, 26(1), pp. 1-16.

Kölling, S. et al., 2019. Sleep-related issues for recovery and performance in athletes. Int J Sports Physiol Perform, 14(2), p. 1440148.

Kraemer, W. J. et al., 2001. Influence of Compression Therapy on Symptoms Following Soft Tissue Injury from Maximal Eccentric Exercise. J Othop Sports Phys Ther, 31(6), pp. 282-90.

Kuligowski, L. A., Lephart, S. M., Giannantonio, F. P. & Blanc, R. O., 1998. Effect of whirlpool therapy on the signs and symptoms of delayed-onset muscle soreness. J Athl Train, 33(3), pp. 222-228.

Lamberts, R. P. et al., 2010. Heart rate recovery as a guide to monitor fatigue and predict changes in performance parameters. Scand J Med Sci Sports, 20(3), pp. 449-457.

Lambing, K. A. & Bender, A. M., 2023. A practitioner's guide to improving sleep in athletes. GSSI Sports Science Exchange, 35(233), pp. 1-6.

Lee, E. C. et al., 2017. Biomarkers in sports and exercise: Tracking health, performance, and recovery in athletes. J Strength Cond Res, 31(10), pp. 2920-2937.

Lindsay, A. & Costello, J. T., 2017. Realising the potential of urine and saliva as diagnostic tools in sport and exercise medicine. Sports Med, 47(1), pp. 11-31.

Lindsay, P. & Pitt, T., 2022. Promoting Athlete Behaviour Change. GSSI Sports Science Exchange, 35(229), pp. 1-5.

Loch, F. et al., 2019. Resting the mind - A novel topic with scare insights. Considering potential mental recovery strategies for short rest periods in sports. Performance Enhancement & Health, 6(3-4), pp. 148-155.

Logue, D. M. et al., 2020. Low Energy Availability in athletes 2020: An updated narrative review of prevalence, risk, within-day energy balance, knowledge, and impact on sports performance. Nutrients, 12(3), p. 835.

Lombardi, G., Ziemann, E. & Banfi, G., 2017. Whole-body cryotheraphy in athletes: From therapy to stimulation. An updated review of the literature. Front Physiol, 8(258).

Lundstrom, C. J., Foreman, N. A. & Blitz, G., 2023. Practices and applications of heart rate variability monitoring in endurance athletes. Int J Sports Med, 44(1), pp. 9-19.

Mastin, D. F., Bryson, J. & Corwyn, R., 2006. Assessment of sleep hygiene using the Sleep Hygiene Index. J Behav Med, 29(3), pp. 223-7.

McGorm, H., Roberts, L. A., Coombes, J. S. & Peake, J. M., 2018. Turning up the heat: An evaluation of the evidence for heating to promote exercise recovery, muscle rehabilitation and adaptation. Sports Med, 48(6), pp. 1311-1328.

McKay, A. K., Sim, M. & Peeling, P., 2023. Micronutrient considerations for the female athlete. GSSI Sports Science Exchange, 36(238), pp. 1-6.

McLaren, S. J. et al., 2018. The relationships between internal and external measures of training load and intensity in team sports: A meta-analysis. Sports Med, 48(3), pp. 641-658.

McNair, D. M., Lorr, M. & Droppleman, L. F., 1971. Manual for the Profile of Mood States. San Diego, CA: Educational and Industrial Testing Services.

Meeusen, R. et al., 2013. Prevention, diagnosis, and treatment of the overtraining syndrome: joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. Med Sci Sports Exerc, 45(1), pp. 186-205.

Mero, A., Tornberg, J., Mäntykoski, M. & Puurtinen, R., 2015. Effects of far-infrared sauna bathing on recovery from strength and endurance training sessions in men. Springerplus, Volume 4, p. 321.

Micklewright, D., Gibson, A. S., Gladwell, V. & Salman, A. A., 2017. Developement and validity of the rating-of-fatigue scale. Sports Med, 47(11), pp. 2375-2393.

Mika, A. et al., 2016. Comparison of Two Different Modes of Active Recovery on Muscles Performance after Fatiguing Exercise in Mountain Canoeist and Football Players. PLoS One, 11(10).

Minett, G. M. et al., 2022. Peer presence increases session ratings of percieved exertion. Int J Sports Physiol Perform, 17(1), pp. 106-110.

Moore, E. et al., 2023. Effects of Cold Water Immersion Compared with Other Recovery Modalities on Athletic Performance Following Acute Strenuous Exercise in Physically Active Participants: A Systematic Review, Meta-Analysis, and Meta-Regression. Sports Med, 53(3), pp. 687-705.

Moore, E. et al., 2022. Impact of Cold-Water Immersion Compared with Passive Recovery Following a Single Bout of Strenuous Exercise on Athletic Performance in Physically Active Participants: A Systematic Review with Meta-analysis and Meta-regression. Sports Med, 52(7), pp. 1667-1688.

Morgan, W. P. et al., 1987. Psychological monitoring of overtrainig and staleness. Brit J Sports Med, 21(3), pp. 107-114.

Morton, R. H., Fitz-Clarke, J. R. & Banister, E. W., 1985. Modeling human performance in running. J Appl Physiol, 69(3), pp. 1171-7.

Myrer, J. W., 1994. Contrast therapy and intramuscular temperature in the human leg. J Athl Train, 29(4), pp. 318-322.

Nässi, A. et al., 2017. Develpment of two short measures of recovery and stress in sport. Eur J Sport Sci, 17(7), pp. 894-903.

National Sleep Foundation, 2020. What is Sleep Quality?. [Online]

Available at: https://www.thensf.org/what-is-sleep-quality/#:~:text=Sleep%20quality%20is%20the%20measurement%20of%20how%20well,you%20feel%20about%20the%20sleep%20you%20are%20getting.

[Accessed 8 April 2024].

National Sleep Foundation, 2021. The Benefits of Napping. [Online]

Available at: https://www.thensf.org/the-benefits-of-napping/#:~:text=Helping%20you%20feel%20refreshed%20to%20meet%20the%20demands,and%20energy%20level%2C%20are%20all%20benefits%20of%20napping.

[Accessed 8 April 2024].

Oliva-Lozano, J. M. et al., 2024. Blood flow restriction as a post-exercise recovery strategy: A systematic review of the current status of the literature. Biol Sport, 41(3), pp. 191-200.

Ortiz Jr, R. O., Sinclair Elder, A. J., Elder, C. L. & Dawes, J. J., 2019. A Systematic Review on the Effectiveness of Active Recovery Interventions on Athletic Performance of Professional-, Collegiate-, and Competitive-Level Adult Athletes. J Strength Cond Res, 33(8), pp. 2275-2287.

Page, W., Swan, R. & Patterson, S. D., 2017. The effect of intermittent lower limb occlusion on recovery following exercise-induced muscle damage: A randomized controlled trial. J Sci Med Sport, 20(8), pp. 729-733.

Papacosta, E. & Nassis, G. P., 2011. Saliva as a tool for monitoring steroid, peptide and immune markers in sport and exercise science. J Sci Med Sport, 14(5), pp. 424-34.

Pedlar, C. R., Newell, J. & Lewis, N. A., 2019. Blood biomarker profiling and monitoring for high-performance physiology and nutrition: Current perspectives, limitations and recommendations. Sports Med, 49(Suppl 2), pp. 185-198.

Peeling, P., Sim, M. & McKay, A. K., 2023. Contemporary approaches to the identification and treatment of iron deficiency in athletes. GSSI Sports Science Exchange, 36(239), pp. 1-7.

Plews, D. J. et al., 2013. Training adapration and heart rate variability in elite endurance athletes: Opening the door to effective monitoring. Sports Med, 43(9), pp. 773-81.

Plews, D. J. et al., 2017. Comparison of heart-rate-variability with smartphone photoplethysmography, Polar H7 chest strap and electrocardiography. Int J Sports Physiol Perform, 12(10), pp. 1324-1328.

Poppendieck, W. et al., 2016. Massage and performance recovery: A meta-analytical review. Sports Med, 46(2), pp. 183-204.

Res, P., 2014. Recovery nutrition for football players. GSSI Sports Science Exchange, 27(129), pp. 1-5.

Rose, C. et al., 2017. Whole-body Cryotherapy as a Recovery Technique after Exercise: A review of the literature. Int J Sports Med, 38(14), pp. 1049-1060.

Rushall, B. S., 1990. A tool for measuring stress tolerance in elite athletes. J Appl Sport Psychol, 2(1), pp. 51-66.

Russell, S. et al., 2019. What is mental fatigue in elite sport? Perceptions from athletes and staff. Eur J Sport Sci, 19(10), pp. 1367-1376.

Russell, S. et al., 2021. Mental fatigue over 2 elite netball seasons: A case for mental fatigue to be included in athlete self-report measures. Int J Sports Physiol Perform, 17(2), pp. 160-169.

Russell, S., Johnston, R. D., Stanimirovic, R. & Halson, S. L., 2023. Global practitioner assessment and management of mental fatigue and mental recovery in high-performance sport: A need for evidence-based best-practice guidelines. Scand J Med Sci Sports, 34(1), pp. 1-15.

Salimetrics, 2024. Salivary SIgA. [Online]
Available at: https://salimetrics.com/analyte/salivary-secretory-immunoglobulin-a/ .
[Accessed 13 March 2024].

Samuels, C., James, L., Lawson, D. & Meeuwisse, W., 2016. The Athlete Sleep Screening Questionnaire: A new tool for assessing and manaing sleep in elite athletes. Br J Sports Med, 50(7), pp. 418-22.

Sands, W. A. et al., 2013. Stretching and it's effect on recovery. Strength Cond J, 35(5), pp. 30-36.

Sawka, M. N., Cheuvront, S. N. & Kenefick, R. W., 2015. Hypohydration and human performance: Impact of environment and physiological mechanisms. Sports Med, 45(Suppl 1), pp. 51-60.

Schneider, C. et al., 2018. Heart rate monitoring in team sports - A conceptual framework for contextualising heart rate measures for training and recovery prescription. Front Physiol, 9(639).

Shirreffs, S. M. & Sawka, M. N., 2011. Fluid and electrolyte needs for training, competition, and recovery. J Sports Sci, 29(Suppl 1), pp. 39-46.

Smith, M. R. et al., 2019. Comparing the effects of three cognitive tasks on indicators of mental fatigue. J Psychol, 153(8), pp. 759-783.

Soligard, T. et al., 2016. How much is too much? (Part 1) International Olympic Comittee consensus statement on load in sport and risk of injury. Br J Sports Med, 50(17 Suppl 1), pp. 1030-1041.

Stephens, J. M. et al., 2017. Cold-water immersion for athletic recovery: One size does not fit all. Int J Sports Physiol Perform, 12(1), pp. 2-9.

Tardy, A. et al., 2020. Vitamins and minerals for energy, fatigue and cognitition: A narrative review of the biochemical and clinical evidene. Nutrients, 12(1), p. 228.

Thomas, D. T., Erdman, K. A. & Burke, L. M., 2016. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. Medicine and Science in Sports and Exercise, 48(3), pp. 543-568.

Thompson, C. J. et al., 2022. Understanding the presence of mental fatigue in elite female football. Res Q Exerc Sport, 93(3), pp. 504-515.

Thorpe, R. T., 2021. Post-exercise recovery: Cooling and heating, a periodized approach. Front Sports Act Living, Volume 3, pp. 1-6.

Thorpe, R. T., Atkinson, G., Drust, B. & Gregson, W., 2017. Monitoring fatigue status in Elite Team-Sport Athletes: Implications for practice. 12(Suppl 2), pp. 27-35.

Tipton, M. J. et al., 2017. Cold water immersion: Kill or cure?. Exp Physiol, 102(11), pp. 1225-1355.

Valie, J., Halson, S. L., Gill, N. & Dawson, B., 2008. Effect of hydrotherapy on the signs and symptoms of delayed onset muscle soreness. Eur J Appl Physiol, 102(4), pp. 447-55.

Van Cutsem, J. et al., 2017. The effects of mental fatigue on physical performance: A systematic review. Sports Med, 47, pp. 1569-1588.

van Hooren, B. & Peake, J. M., 2018. Do We Need a Cool-Down After Exercise? A Narrative Review of the Psychophysiological Effects and the Effects on Performance, Injuries and the Long-Term Adaptive Response. Sports Med, 48(7), pp. 1575-1595.

van Loon, L. J., 2021. Plant versus animal-based proteins to support muscle conditioning. GSSI Sports Science Exchange, 34(220), pp. 1-7.

Versey, N. G., Halson, S. L. & Dawson, B. T., 2013. Water immersion recovery for athletes: Effect on exercise performance and practical recommendations. Sports Med, 43(11), pp. 1101-30.

Viitasalo, J. T. et al., 1995. Warm underwater-jet massage improves recovery from intense physical exercise. Eur J Appl Physiol Occup Physiol, 71(5), pp. 431-8.

Wallis, G. A. & Podlogar, T., 2022. Dietary carbohydrate and the endurance athlete: Contemporary perspectives. GSSI Sports Science Exchange, 35(231), pp. 1-6.

Walsh, N. P. et al., 2020. Sleep and the athlete: Narrative review and 2021 expert consensus recommendations. Br J Sports Med, pp. 1-13.

Wang, L., Fang, M. & Hu, J., 2022. The effect of vibration massage on fatigue of the upper trapezius during different tasks. Symmetry, 14(10), p. 2158.

Wang, R. et al., 2017. Accuracy of wrist-worn heart rate monitors. JAMA Cardiol, 2(1), pp. 104-106.

Watanuki, S. & Murata, H., 1994. Effects of wearing compression stockings on cardiovascular responses. Physiol Anthropol, Volume 13, p. 121.

Weakley, J. et al., 2022. Putting the Squeeze on Compression Garments: Current Evidence and Recommendations for Future Research: A Systematic Scoping Review. Sports Med, 52(5), pp. 1141-1160.

Weerapong, P., Hume, P. A. & Kolt, G. S., 2005. The Mechanisms of Massage and Effects on Performance, Muscle Recovery and Injury Prevention. Sports Med, 35(3), pp. 235-256.

Wiewelhove, T. et al., 2019. A Meta-Analysis of the Effects of Foam Rolling on Performance and Recovery. Front Physiol, 10(376).

Wilcock, I. M., Cronin, J. B. & Hing, W. A., 2006. Physiological response to water immersion. Sports Med, 36(9), pp. 747-765.

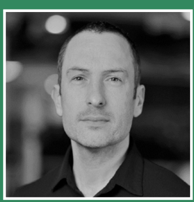
Williams, D. A. et al., 2002. Improving physical functional status in patients with fibromyalgia: a brief cognitive behavioural intervention. J Rheumatol, 29(6), pp. 1280-6.

Yamuna, P. & Muthu, P., 2017. Methods of collection of saliva - A review. Int J Oral Health Dent, 3(3), pp. 149-153.

MEET THE TEAM

LIAM BROWN, MSc
GSSI SCIENTIST

Liam is a Scientist for the GSSI International team, based in the UK. Liam earned his Bachelor's Degree in Nutrition and Food Science from the University of Reading, before completing a Master's Degree in Sport Nutrition at Liverpool John Moores University in 2018. Liam has previously worked as Head of Sport Nutrition for a Professional English Soccer Club, as well as working as a Nutritionist in the Food Industry. Liam's current role with GSSI involves the provision of sports nutrition support for Gatorade Partners, including professional soccer club Manchester City Football Club. In addition, Liam is responsible for managing and supporting GSSI service and education engagements internationally. This includes the production of novel education resources, like the GSSI Sports Nutrition Toolkit, delivering workshops and presentations globally and providing nutrition and hydration support to those with physically demanding occupations.



IAN ROLLO, PhD
GSSI PRINCIPAL SCIENTIST

Ian is principal scientist and head of GSSI International performance service engagements. His current role involves providing sports science and sports nutrition support for professional soccer clubs and organizations such as Manchester City FC and UEFA. His research is focused on sports nutrition and exercise physiology. Ian earned his Bachelor's degree from Birmingham University in sport and exercise science and Master's degree from Loughborough University in Exercise Physiology. In 2009 he received a PhD from Loughborough University under the supervision of Professor Clyde Williams. In 2005 he worked at the August Krogh Institute, Denmark, assisting in studies on mechanisms of fatigue during high intensity exercise and optimizing nutritional strategies for soccer. Ian has previously served as a performance consultant in professional soccer, swimming and rugby. Dr Rollo is an honorary research fellow at Loughborough University, where he previously led MSc module on Sport and Exercise Nutrition. Ian also manages PepsiCo clinical research projects and is involved in developing novel technologies to support athletic performance. Finally, Ian leads the PepsiCo innovation team on healthy aging. He continues to author publications and deliver invited presentations globally.

ACKNOWLEDGEMENTS

We would like to thank our GSSI colleagues Jon Kyle Davis, Caroline Tarnowski, Kevin Luhrs, Kim Stein, Anthony Wolfe, Khalil Lee and Rebecca Randell for their expert review and contributions to this Toolkit.

LB and IR are employees of the Gatorade Sports Science Institute, a division of PepsiCo, Incorporated. The views expressed in this book are those of the authors and do not necessarily reflect the position or policy of PepsiCo, Incorporated.

Pounds	Stones		Kilograms
lb	st	lb	kg
130	9	4	59.97
140	10	0	63.50
150	10	10	68.04
160	11	6	72.58
170	12	2	77.11
180	12	12	81.65
190	13	8	86.18
200	14	4	90.72
220	15	10	99.79
230	16	6	104.33
240	17	2	108.86

Mass Conversion Rates	
Pounds to Kilograms	1 pound is equivalent to 0.4536 kilograms
Kilogram to Pounds	1 kilogram is equivalent to 2.205 pounds
Stones to Pounds	1 stone is equivalent to 14 pounds
Stones to Kilograms	1 stone is equivalent to 6.35 kilograms

Table 25

A conversion table from pounds to kilograms

MEASUREMENT CONVERSION TABLES	
Grams	Ounces
g	oz
5	0.18
10	0.35
15	0.53
20	0.71
25	0.88
28 (1 ounce)	1.00
30	1.06
35	1.23
40	1.41
45	1.59
50	1.76
55	1.94
60	2.12
65	2.29
70	2.47
75	2.65
80	2.82
85	3.00
90	3.17
95	3.35
100	3.53
227 (½ pound)	8.00
454 (1 pound)	16.00
1000 (1 kilogram)	35.30
Mass Conversion Rates	
Grams to Ounces	1 gram is equivalent to 0.03527 ounces
Ounces to Grams	1 ounce is equivalent to 28.35 grams
Pounds to ounces	1 pound is equivalent to 16 ounces
Pounds to grams	1 pound is equivalent to 453.6 grams

Table 26

A conversion table from grams to ounces.

MEASUREMENT CONVERSION TABLES

US Fluid Ounces	Millilitres	UK Fluid Ounces
fl oz	ml	fl oz
3	100	4
5	150	5
7	200	7
9	250	9
10	300	11
12	350	12
14	400	14
15	450	16
17	500	18
19	550	19
20	600	21
22	650	23
24	700	25
25	750	26
27	800	28
29	850	30
30	900	32
32	950	33
34	1000	35

Fluid Conversion Rates

US Fluid Ounce to Millilitres	1 US fluid ounce is equivalent to 29.6 millilitres
Millilitres to US Fluid Ounce	1 millilitre is equivalent to 0.03381 US fluid ounces
UK Fluid Ounce to Millilitres	1 UK fluid ounce is equivalent to 28.4 millilitres
Millilitres to US Fluid Ounce	1 millilitre is equivalent to 0.0352 UK fluid ounces

Table 27

A conversion table from fluid ounces to millilitres.

GATORADE SPORTS SCIENCE INSTITUTE™

GATORADE SPORTS SCIENCE INSTITUTE™

GATORADE SPORTS SCIENCE INSTITUTE™