

Chapter 8: Introduction to physiology

by Wayne Goldsmith

The study of the human body's structures, systems, tissues and cells is called physiology. The application and understanding of how the human body responds and adapts to exercise or sport is known as sports physiology.

Success in sport relies on the optimal development of the physical, mental, technical and tactical elements of performance. At the core of every performance is the physiological or physical preparation of the athlete.

Coaches are always looking for a performance edge through a new idea or innovative technique that might provide their athletes with an advantage over their opponents. Sports science is not a magic trick and there are no short cuts to the top. The methods and techniques of sports science are tools, and like the tools of any trade their effectiveness lies in the skills and knowledge of the user. The information contained in this chapter offers the coach simple but effective tools so they can systematically plan, implement, monitor and modify training programs for their athletes and so achieve their sporting goals.

Energy systems in sport

The human body is a complex machine comprising the following systems and structures working together to sustain life:

- . cardiovascular system (the heart and blood vessels) — delivers blood carrying oxygen and vital nutrients to working muscles and tissues
- . endocrine system (tissues and glands that secrete hormones) — sends chemical signals around the body that affect specific organs, tissues and cells
- , musculoskeletal system (muscles, joints, ligaments, tendons and bones) — produces movement and structural stability for the body
- . nervous system (brain and nerves) — regulates, integrates, stimulates and monitors internal and external information.

The energy to power sporting movements comes from a range of complex biochemical processes and chemical reactions occurring in different tissues and cells around the body.

Aerobic energy system

Some of these reactions occur using oxygen and these are known as aerobic (think AIR-obic).

Characteristics of aerobic activities include:

- . low intensity, around 65–75 per cent of maximum intensity
- . long duration, either continuous or with limited rest periods
- . usually programmed early in the season.

The aerobic system is used in sports that require a sustained and enduring expenditure of energy. Training activities that improve cardiovascular efficiency and aerobic energy production are called aerobic training. Jogging, cross country skiing, road cycling and long-distance swimming are all examples of aerobic training.

The body adapts to aerobic training by improving:

- . the ability of cells to use oxygen
- . the capacity of the blood vessels to deliver oxygen to working muscles
- . oxygen transport mechanisms.

Anaerobic energy system

Other reactions and processes in the body are able to produce energy quickly in response to a need for speed, power or explosiveness, and this is known as anaerobic (think a-NO-AIR-obic).

The anaerobic system has two components:

- . the lactic acid system
- . the alactic (meaning without lactic acid) system, also known as the phosphate system.

Anaerobic activities are typically high intensity and short duration. Anaerobic training activities are those that improve the functioning of anaerobic energy-producing systems and physical abilities such as power and strength, including:

- . lactic anaerobic activities — those of sustained high intensity, such as the 400-metre run on the track and the 100-metre swim in the pool
- . alactic anaerobic activities — those that are explosive, of short duration and high intensity, such as a single lift in a power lift or a high jump.

Alactic training is often used in the development of the neural system, also known as the nervous system, which is best stimulated in an environment without fatigue or significant lactic acid being present.

Systems working together: total energy demands and total energy production

It is a common misunderstanding that the body's energy-producing systems are separate systems operating independently of each other. In reality, both the aerobic and anaerobic systems work to produce energy in all sporting activities. It is the relative contribution of each system that changes with the intensity and duration of the activity.

Alactic anaerobic system

In a 100-metre sprint on the track, for example, the dominant energy supply comes from the alactic anaerobic system, which produces energy quickly and can use energy already present in the muscles cells. Other energy systems continue to operate; however, their relative contribution to total energy production is small, as shown below.

100m sprint = **ALACTIC ANAEROBIC** LACTIC ANAEROBIC AEROBIC

Lactic anaerobic system

In a sustained high intensity activity such as a 400-metre run on the track lasting 40 seconds or more and at near maximum intensity, the body relies more on energy production from the lactic anaerobic system and the relative contribution of the other systems is smaller, as shown below.

400m run = **ALACTIC ANAEROBIC** **LACTIC ANAEROBIC**

Aerobic system

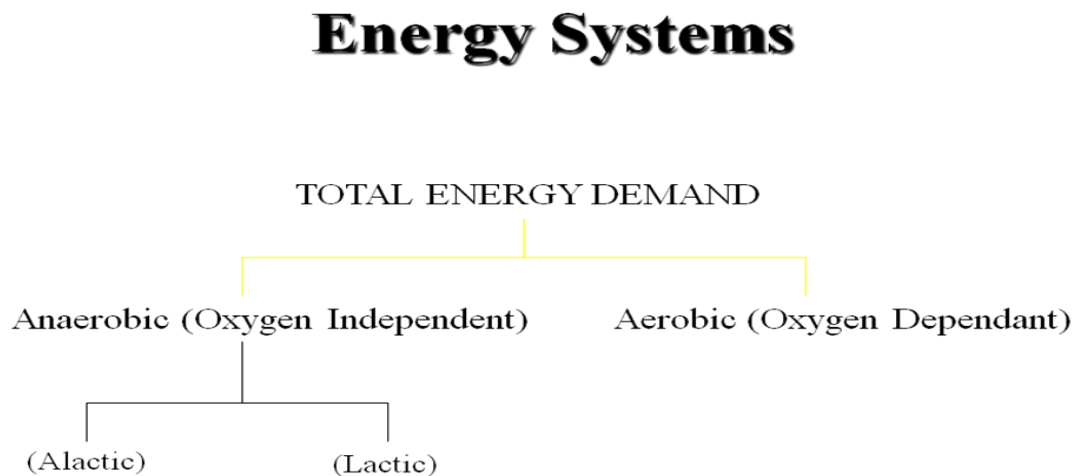
In longer events such as distance running or long-distance cycling, where energy demands are lower but need to be sustained for longer, the aerobic system is the dominant energy-production system as shown below.

Distance events = **ALACTIC ANAEROBIC** LACTIC ANAEROBIC **AEROBIC**

Team sports

In team sports, the relative contribution of the energy-producing systems will vary over the course of the game, depending on position, tactics, strategies and game activity.

Figure 8.1: Energy systems



Anaerobic and aerobic energy systems contribute to energy production in all activities.

Metabolic processes do not act independently but occur simultaneously and are fully integrated to provide the required energy. Relative contributions of energy systems are dependent on overall **intensity** and **duration** of exercise.

In the past, sports science has made general recommendations on training energy systems in specific sports. The trend for coaches now is to individualise training programs for each athlete and develop the athlete's energy systems based on the unique needs of each person, rather than apply broad, non-specific physiology principles.

Analysis of needs

Every coach needs to understand the performance demands of their athletes in a competition setting and from there they can develop appropriate and effective individual training programs. One way of doing this is to undertake a performance analysis of needs. This can be as simple as using a stop watch in a time-and-motion study and recording the time an athlete spends standing still, walking, striding, jogging, sprinting or jumping during a game. It could also include

using a video camera to record and then analyse an athlete's performance or physiology testing.

Monitoring training intensity

The basic measurement and monitoring tools of sports physiology for coaches are:

- . heart rate
- . energy systems — training zones
- . perceived exertion.

These are used to help determine how hard the athlete is working. This is a key training concept known as the exercise intensity. While the volume of training, or how much training an athlete does, is an important issue, it is the intensity of training that is the key to how the athlete responds and adapts to both the immediate and longer-term effects of the training program.

Training adaptations, fatigue, recovery and other fundamental physical changes are all directly affected by training intensity. To be successful, coaches must have a thorough understanding of training intensity, how to manipulate it to achieve performance goals and, very importantly, how to measure and monitor it.

Performance versus physiological measures of exercise intensity

It is important to distinguish between performance and physiological measures of intensity.

- . Performance measures, or primary measures — are the more constant and controllable measures, such as running speed, court time, number of tackles or rebounds, free throws or kicks. These can be accurately and reliably measured and recorded.
- . Physiological measures, or secondary measures — are those that assess or evaluate the physiological responses to an activity, such as heart rate and breathing rate. These cannot be measured as readily or with the same accuracy as the performance measures and are subject to the influence of other internal or external factors.

Analysis of the physical demands and fitness requirements of a sport requires the application and understanding of both performance and physiological measures.

Heart rate

In sports physiology, heart rate is commonly used to monitor exercise intensity and is described in terms of beats per minute. The heart contracts between 50 and 80 beats per minute in the average person at rest. As the person increases physical activity, the heart responds to the increasing need for oxygen and blood supply by increasing its rate of contracting; that is, the number of beats per minute increases in direct relation to the intensity of a physical activity. In this way, the heart is a type of 'speedometer' for the human body in action. While providing useful information, keep in mind that heart rate can vary due to other factors including caffeine, alcohol and stress, and so heart rate should be just one of the factors a coach uses to determine an athlete's training loads.

Energy systems and training zones

Coaches in the field need simple and reliable measures of exercise intensity. The following five training zones are one way of meeting this need. The coach and athlete can use training zones to prescribe individual training sessions, training sets and drills. For practical purposes the most readily identifiable and useable zones are:

- . recovery level, relaxed, comfortable — very easy aerobic
- . low intensity — easy aerobic
- . high intensity, sustained pace work (also called threshold training) — anaerobic and aerobic
- . specific pace work at the intensity of the targeted competition — anaerobic and aerobic
- . speed development work (neuromuscular training) — alactic anaerobic.

In a laboratory setting with an individual athlete it is possible to identify other training zones; however, these five are easy to use and meet most training needs in most sports.

Perceived exertion

The concept of perceived exertion relies on the subjective judgment and 'feel' of the athlete. The athlete is asked to provide feedback on the intensity level of the training activity or how hard the training activity feels.

For example, an athlete may be asked to do a training activity at a specific intensity level. The coach may want to prescribe the intensity level not in terms of objective measurements such as

speed or time, but in terms of how the athlete ‘feels’ the effort. To help with this process, coaches and athletes can develop simple scales that are practical and meaningful to them, such as the following one. In combination with other measurements it can give a relatively accurate understanding of the athlete’s intensity level.

Intensity level	Feels like	Equates to
1	Very relaxed	Recovery
2	Easy	Easy aerobic
3	Tough	Threshold
4	Very hard — uncomfortable	Race pace/near maximal game intensity
5	Fast but not hard	Speed development/neural

When using perceived exertion levels, it is important to remember that each athlete’s opinion about how things ‘feel’ applies to that individual only. A ‘four’ for one athlete, for example, may feel like a ‘two’ for another athlete. There may also be some day-to-day variation in feel as the athlete’s level of fatigue, motivation, attitude and recovery status change.

So what is the best way for a coach to determine the intensity level of training activities? The coach must determine the most appropriate, relevant and meaningful way of monitoring training intensity in their athletes. As athletes become more experienced, it is important that the coach takes time to demonstrate and teach athletes to self-manage and self-monitor, so that the athletes themselves can determine accurate training loads. Ideally the best way to manage exercise intensity is to use a combination of two or more of the physiological measurement techniques.

Case study

Pauline and her coach Louise are working together to monitor training load and have a training session scheduled at the track. Louise has determined that today’s run should be completed at a moderate pace. She gives this information to Pauline in three different ways, starting with telling her to run three kilometres at about a 12-minute pace. She goes on to suggest a six-out-of-ten pace, which she felt would be just steady running for Pauline (or in other words, a moderate effort). At the end of the run, Louise takes Pauline’s heart rate to add to the other

information about how hard her body is working at that pace. Louise and Pauline then discuss how the run felt and provide feedback to each other as follows:

Louise: 'It looked good. It looked comfortable. How did it feel?'

Pauline: 'It felt easy. About six out of ten. What was my time?'

Louise: 'The time was 11.57. Nice pacing'.

Pauline: 'What about heart rate?'

Louise: 'Pretty comfortable — about 140 beats per minute.'

As a result of this discussion, Louise has useful information from the training session to then determine whether training is going according to plan or whether changes need to be made in order to achieve the longer-term program goals.

It is important to educate athletes on how to monitor, measure and manage their own bodies and how they are responding and adapting to training loads. Information on performance, fatigue, sleep, mood and attitude, as well as general health and wellbeing, can provide valuable feedback to the coach and athlete on the progress of the training program.

Many sports are now investigating the use of online monitoring tools to assist their coaches, staff and athletes in the capture, recording and analysis of this important information.

Fitness for sport

Components of fitness

For the general public, fitness usually relates to weight management, good health and regular exercise. In a sports context, it is the capacity of an athlete to perform in their chosen sporting activity.

Some capacities are genetically determined and cannot be trained (for example, height).

However, other capacities such as strength, flexibility and endurance can be trained, and it is on these changeable elements of an athlete's physical capacity that training programs are focused. Training these capacities is an ongoing coaching challenge, as attributes such as flexibility can show changes within a week, but strength and endurance, for example, can take significantly longer to show gains — sometimes weeks or even months.

Every sport is different and requires programs designed specifically for that sport and specifically for those athletes. Fitness for a long-distance runner, for example, will focus on

endurance and speed. For an Australian football player it will be based on endurance, speed and agility. A hockey goalkeeper's fitness, on the other hand, may be measured in terms of power, flexibility and agility. A coach will use their knowledge of the components of fitness when prescribing a training program to include an appropriate balance of exercise intensity and volume (duration) as well as frequency and recovery.

The building blocks of performance

Speed is how fast an athlete moves from point A to point B.

The measurement and development of speed involves a number of different elements, including:

- . reaction time — the time it takes for an athlete to react (move) in response to a stimulus
- . acceleration — how fast an athlete increases speed
- . maximum velocity or speed — the maximum speed an athlete can attain.

A 100-metre sprint on the track, 50-metre sprint in the pool and an all-out sprint down the court are all examples of speed.

Strength is the ability or capacity of muscles to apply force, such as in weightlifting, grappling with an opponent in wrestling or pushing in a rugby scrum. It is a key element of power and speed.

Power is the rate of force application or explosiveness. Put simply, it is how much force can be applied in the shortest possible time. The rate of performing work must have a force or load component as well as a speed or velocity component.

$$\text{Power} = \text{force (strength)} \times \text{velocity (speed)}$$

Power in sport can be seen in jumping high to take a catch in handball, a mark in Australian football, starts in track and field or swimming, and throwing a shot-put.

Endurance is the capacity to perform an activity repeatedly, to go longer or to resist fatigue. A muscle's or muscle group's capacity to resist fatigue is called muscular endurance. Examples of endurance can be seen in marathon running, road cycling or Australian football. In team sports, repeated sprint ability is an important endurance adaptation. It allows players to repeat short bursts of high intensity, high-speed efforts. This ability is critical in team sports such as hockey when possession of the ball changes frequently in a short time, requiring players to sprint into attacking and defensive positions with limited rest between sprints.

Agility is an ability to change direction quickly. It is important, for example, in the football codes when side-stepping an opponent, as well as in floor routines in gymnastics. In court sports it is key when turning quickly and competing with opponents travelling in the opposite direction.

Baking the performance cake

Designing a training program with the right mix of performance elements such as speed and endurance is just like making a cake. With a cake, there is a recipe that explains how many eggs and how much flour, how long to beat it and how long to let it stand. Then there are details on how hot to have the oven and how long to bake it. If the cook is in a rush and adds too much butter, no eggs and then, in a moment of misguided enthusiasm, add a few cups of flour more than the recipe needs (because they would like it a little larger than the one in the picture), then even if the temperature is right, the cooking time is not, and what you get is a brick, not a dessert!

Training is a mix of the right things done at the right time in the right quantities. It all starts with the training plan, which is the 'recipe' for success. The training plan includes lots of ingredients such as endurance, speed, power, technique training, skill training and gym work. It is mixing these training ingredients correctly that makes all the difference. If an athlete does too much endurance without mixing in some speed work, gym work and flexibility, they will not get the success they deserve. With not enough endurance training, athletes will fatigue in the latter stages of races and games. It is the balance of training 'ingredients' that makes a great performance 'cake'.

While it is convenient to categorise unique and separate training types such as speed or endurance, it is also popular to include cross training in effective training programs. Cross training is the incorporation of different training types or training for different sports within the same training cycle (for example, distance runners incorporating cycling into their training program, or football players including tennis to improve agility and fitness).

Types of training

Each type of physical ability or capacity can be changed, improved or developed based on the appropriate application of a training stimulus.

Endurance training examples

Type of training	Characteristics	Examples	Pros	Cons	Coaching issues
Distance	<p>Long duration</p> <p>Continuous</p> <p>Rhythmic</p> <p>Low intensity — that is, less than 80 per cent of maximum.</p> <p>The primary goal is duration of exercise, rather than speed or intensity</p>	<p>Long distance running, cycling, swimming</p>	<p>Efficient form of endurance development</p>	<p>Can be boring for athletes</p> <p>Can increase risk of overuse injury</p>	<p>Balancing the need for long, slow, continuous training with the practicality of keeping athletes motivated and stimulated by the training environment</p>
Fartlek	<p>Speed 'play'</p> <p>Changing movement speed with mood, terrain, recovery</p>	<p>Running around a golf course and surging up hills</p> <p>Swimming ten laps and sprinting the first five metres each lap</p>	<p>Can be an interesting and stimulating training type with countless variations</p> <p>Based on the athlete's 'feel' rather than a pre-prescribed load that may be inappropriate</p>	<p>Athletes may do too much at an inappropriate intensity level, resulting in the need for significant changes to the training program</p>	<p>Measuring work actually completed</p>
Interval training	<p>Training activities of relatively short duration interspersed with rest/recovery periods; that is, an 'interval' of work followed by an</p>	<p>Running 10 x 200-metre efforts holding a time of 35 seconds for each 200 with a one-minute</p>	<p>Easy to manage and measure workload</p> <p>Variety in workloads including</p>	<p>Relatively higher intensity can lead to increased injury risk</p>	<p>Great opportunity for feedback and coaching comments between work</p>

	'interval' of rest	rest between each	distance, speed, terrain and recovery	Too much focus on time and effort, rather than skills and technique	intervals
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Strength training

Strength is the maximum force or tension generated by a single muscle or group of muscles. Strength or resistance training involves using weights or other external loads to overcome a fixed initial resistance to strengthen specific muscles. The muscle cells adapt to the extra workload by increasing in size and recruiting greater numbers of nerve cells to cause a muscle contraction.

Strength training can be a useful supplement to sport-specific training. Effective strength training programs use a wide range of techniques and skills to enhance the athlete's ability to perform in competition. The key question for every coach, however, must be whether the strength and conditioning activity the athletes are doing directly (through increased power or strength) or indirectly (through injury prevention or early season conditioning) contributes to improved competition performances.

When setting strength training programs, the following terms are used:

- . repetition — a single complete movement of an exercise or activity. One push-up is one repetition; one chin-up is one repetition
- . set of repetitions or simply a set — a series or group of repetitions performed continuously without rest. Ten push-ups completed without rest is known as a set of ten push-ups.
- . repetition maximum — the maximum number of repetitions that can be completed in a single set with a given resistance.

Strength training examples

Type of training	Characteristics	Examples	Pros	Cons	Coaching issues
Body-weight	Lifting own body	Push-ups, chin-ups,	Easy to learn	Athletes can get bored and	Transfer of increased

resistance training	weight	dips, stair climbing, rope climbing	Inexpensive Practical — can be done anywhere and anytime Easy to measure improvement	tired of the training environment	strength to improved competition performance
Weight training	Lifting an external resistance; for example, weights	Gym work; that is, lifting free weights, using weights machines	Variety of the training environment Training load can be easily measured and manipulated	Importance of learning correct lifting techniques Need for partner to assist in safe lifting Cost of gym access	Need to control the weight-training environment to ensure safety, correct technique and sensible progression are adequate Transfer of gym strength to improved competition performance
Circuit training	Combination of movements, loads, equipment and exercises in a systematic programmed training activity. Circuit activities are usually rapid, moderate to high intensity performed in a sequence with short rest periods in	Jumping followed by throwing followed by a short jog. Thirty seconds rest then ten push-ups, 20 step-ups and another short jog	Variety of the training environment Enjoyable group training environment Can be used to simulate competition environment	Difficult to quantify or measure exact training load	Transfer of circuit activities to game/competition environment

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Flexibility training examples

Type of training	Characteristics	Examples	Pros	Cons	Coaching issues
Dynamic stretching	Stretching to the limits of the range of motion using fast, sport-specific movements	Arm or leg swinging movements to the limits of range of motion	Stretching through a range of movement at speeds close to those of the competition environment	Increased risk of soft tissue injury if athlete does not warm up appropriately	Care needs to be taken to ensure athletes are warmed up and prepared appropriately before attempting dynamic stretches
Static stretching	Holding a stretch in a single position near the point of maximum stretch for 30–60 seconds	Standing hamstring stretch with the leg parallel to the ground	Controlled movements mean minimal injury risk Range of motion can be increased, particularly if static stretches are held for 30–60 seconds post-exercise	Static nature of the stretching is not specific to the movements of most sporting activities	Athletes should be educated to hold the stretches while staying relaxed and controlling breathing
Partner stretching	Working with a partner in stretching exercises and flexibility routines	One athlete executing a shoulder stretch while their partner	A partner can help an athlete achieve an increased level of stretch that the	Danger of overstretching if both partners do not	Need to educate athletes on how to work together and

		is supporting their shoulder	athlete could not achieve unassisted Can be motivating to work with a partner	communicate effectively	provide continuous feedback to each other
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Speed training examples

Type of training	Characteristics	Examples	Pros	Cons	Coaching issues
Accelerations	Activities which increase athletes' ability to increase speed rapidly	5–10 metre timed sprints Accelerations from slower speeds Leg speed drills	The first 5–10 metres in many team-sport competitive situations are critical in order to overcome or escape an opponent	Injury risk with sudden increases in rate of speed if not adequately warmed up and prepared	Aim should be to train the athletes to achieve their own maximum speed faster
Agility	Activities that teach athletes to change direction quickly	Rapid change of direction drills around cones and obstacles	Agility is a critical component of most team sports, especially football codes, netball, basketball, hockey and volleyball	Sudden deceleration/ acceleration and changes of direction pose a potential injury risk to joints and muscles	Importance of educating athletes to change direction quickly while maintaining technical skills, control, balance and coordination
Reaction	Activities that improve	Five-metre	Improving	Due to the	Simulate the

exercises	<p>athletes' ability to react or move in response to a stimulus</p> <p>Reaction consists of several components, including the receiving of the stimulus by the athlete, the processing of the stimulus by the athlete's brain and nervous system and the initiation of movement in the athlete's muscles</p>	<p>sprint in response to a sudden noise, trigger or stimulus</p> <p>Measuring athletes' response (first movement) to an external stimulus</p>	<p>reaction is a critical competitive skill, and by training reaction athletes can develop an increased ability to compete against an opponent</p>	<p>short time involved, improvement in reaction time can be difficult to measure without electronic measuring equipment</p>	<p>reaction stimulus in training that athletes will be reacting to in competition (for example, a starting signal for sprinters and swimmers or the movement of an opponent for a team-sport athlete)</p>
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Power training examples

Type of training	Characteristics	Examples	Pros	Cons	Coaching issues
Plyometrics	Explosive, powerful movements with minimal rest and minimal contact with the ground	Jumping, hopping, bounding	Effective power development activities that closely simulate many explosive sporting movements	Potential injury risk for athletes who are not strong enough or adequately prepared	Importance of stressing good technique and explosiveness in all plyometric activities
Circuit training for power	Fast, explosive activities performed in a circuit or sequence with minimal rest. Generally few repetitions of each activity are performed	Jumping, hopping, bounding, throwing	Can simulate the repeated power demands of many field games such as football, hockey,	Difficult to measure load	Need to balance power and explosiveness development with fatigue from repeated

	to minimise the impact of fatigue		basketball Can use interesting and stimulating equipment to bound, jump, hop, leap over and around		exercises in the circuit
Weight training for power	Typically 2–4 sets 2–6 repetitions Load relatively light and movement fast and controlled	Most weight-training exercises	Variety Overload can be closely monitored and controlled	General gym safety issues Potential injury risk to joints and muscles at the end of the movements if not controlled	Important to ensure good weight-lifting technique with increasing speed of movement
Terrain power sprints	Short, powerful, explosive sprints with exaggerated running action (for example, high knee lift)	8 x 20 metre sprints up a 5 per cent grade hill with long rests in between each repetition	Very specific overload for running muscles	Changes to running technique if grade is excessive	Important to identify terrain that stimulates power development but does not compromise running technique

The principles of training

Overload

Improvements from training come from working the body and mind a little harder than previously to achieve a training effect. As an athlete develops training loads, the load needs to be increased gradually but progressively to ensure continuing adaptations.

Periodised training that is systematically planned and programmed over time allows for effective development of the appropriate body system. Each training session should have a clear objective and should be evaluated to ensure the appropriateness of the (over) loading.

Increasing an athlete's workload too quickly can lead to overtraining, which can result in excessive fatigue, injury and illness.

Overloading can be done through regular physical training and competition, introducing a new training stimulus or changing the frequency, intensity and volume balance. In the gym, for example, a coach may increase the amount of weight lifted. On the running track, a coach may increase the distance covered in a training session or training period.

RUFIT: Are you fit?

A simple way to remember the fundamentals of overload is the RUFIT system:

- . **Recovery** — ensure adequate focus on recovery between training and competition
- . **Unique** — overload each athlete based on their individual needs, abilities and capabilities
- . **Frequency** — how often athletes train
- . **Intensity** — how hard athletes train
- . **Time (duration/volume)** — how long they train for.

Case study

Sixteen-year-old Hannah is a good club-level volleyball player who has been involved in the sport for five years. She trains with her team three times each week and plays on Saturday afternoons. She has decided to make the commitment to improving her performance with a view to making the state team. Hannah discusses this with her coach, Irena, and together they plan a training program to achieve this goal. They identify that Hannah needs to improve her physical endurance in particular, and make this their first priority.

Irena uses the RUFIT system as a guide to help her plan the new program.

- . **Recovery** — an increased training load means Hannah will need to plan for more rest and recovery, so she decides to reduce the amount of television she watches at night and get some extra sleep.

- . **Unique** — Irena prescribes a training load based on Hannah's individual needs. Hannah has a limited background in endurance training so she decides to balance her endurance training with swimming, cycling and a little jogging.
- . **Frequency** — Hannah is at school, but has some time free in the mornings. Irena includes an endurance training activity on Monday, Wednesday and Friday mornings.
- . **Intensity** — as the goal is to improve endurance performance, Irena sets the intensity level at 75 per cent of Hannah's maximum heart rate and shows Hannah how to take her heart rate accurately during exercise.
- . **Time** — Hannah and Irena decide that given Hannah's training background, 3 x 30-minute endurance training sessions will be sufficient training volume to achieve the training goals.

Progression

Progression is the gradual, systematic and planned increase in training and competition loads. An important aim of progression is to gradually increase the stress and load placed on the body, usually on a specific muscle or muscle group, so that its capacity to produce force or resist fatigue becomes greater. This can be done by gradually increasing the distance an athlete runs in training each week or gradually increasing the amount of weight an athlete lifts in the gym over the season.

The principle of progression underlies all planning decisions in the training program, as the program itself is designed to achieve the set goals systematically and strategically, or in other words, progressively.

Regular testing such as time trials, shuttle runs or speed tests are an important feedback mechanism for the coach and athlete on how the program is progressing.

Testing has four main goals:

- . determining appropriate training zones for the individual athlete
- . ensuring that athletes are coping and adapting to the training programs
- . evaluating the effectiveness of the training programs
- . providing motivation for athletes by demonstrating performance progress.

Regular, accurate and reliable feedback from the athlete can provide a valuable insight into the effectiveness of the training program and the application of the principle of progression.

Case study

Vladimir is an experienced coach who has recently moved to town and taken over a large squad of enthusiastic squash players. The season is about to start and the season plan is already in place; however, he needs to get to know his squad quickly so he can make sure their individual programs are working for them. Vladimir decides that introducing the athletes to self-monitoring is a way to get some of that information, and at the same time educate the athletes to listen to their bodies and learn to take care of themselves. Vladimir develops seven quick questions for the athletes to ask themselves every day that will give both the coach and athlete an insight into how they are adapting to training and how the training progression is working. The questions include:

- . How do I feel today?
- . How well did I sleep last night?
- . How is my attitude?
- . How is my appetite?
- . Are my muscles sore and aching?
- . Do I feel stressed or anxious?
- . Is there anything happening away from the court that I cannot stop thinking about, such as exams or issues with family and friends?

The athletes are asked to answer using a simple scale of 1–5.

- 1 = Poor
- 2 = Fair
- 3 = Average
- 4 = Good
- 5 = Excellent

Vladimir is particularly keen to identify any athletes whose scores are low for more than two or three days, as this can often be an early indication that the athlete is not adapting to the training program and may need more focus on rest, recovery and regeneration.

Recovery

Recovery in sports physiology has been an area of increasing importance and focus in recent years. It is essentially recovering from training and competition loads through resting and

recuperating, which in turn regenerates the body and mind. Many sporting teams have a designated recovery program to support and complement their training and competition program.

Recovery can be approached in many ways, such as quarter-time or half-time breaks in team sports, easy days or sessions in a long-term training program, or off-season breaks after the end of one season and before the beginning of the next. On a day-to-day basis, coaches can support recovery by encouraging athletes to drink plenty of fluids straight after training or competition to replace what has been lost, suggesting a massage (either self-massage or by a massage therapist) and perhaps most importantly, recommending a good night's sleep.

Signs of fatigue

Feeling fatigued or tired after training is normal, but excessive and constant fatigue is not.

When the body is constantly tired, it more easily becomes ill or injured. The body's defence mechanism, known as the immune system, then breaks down leaving the athlete vulnerable to coughs, colds and infections. **More is not better.** An overtrained athlete is one who has done more work than they can physically and mentally tolerate. They will not improve and their performance may even go backwards.

There are several fatigue factors that if monitored regularly can help the athlete manage fatigue levels, maintain good health and achieve optimal training.

These include:

- . sleep — what is the athlete's quality of sleep? Do they fall asleep easily and wake feeling refreshed or do they toss and turn and wake feeling even more tired than the day before? Athletes training hard sleep well. Athletes who are in a state of excessive fatigue will often complain that they have difficulty falling and staying asleep
- . muscle soreness — do the athlete's muscles feel tired after training or are they still sore and aching 2–3 days later? It is normal for muscles to be tired, but it is not normal for muscles to be sore, aching and tight for more than 24–48 hours
- . resting heart rate — as athletes get fitter, their resting heart rate (taken when they first wake) gets lower. If an athlete's heart rate is higher than normal by 10–15 beats per minute for 2–3 consecutive days it might be a sign their body is not adapting to training
- . energy — fit people are high-energy people. Overtrained people feel slow, flat and lethargic, and lacking in energy

- . weight loss — fit, healthy people tend to keep an energy balance where weight is neither gained nor lost. In an overtrained or tired state, body weight can fluctuate by 1–2 kilograms (or more) in 24 hours
- . ‘feel’ — tired swimmers will often say, ‘I can’t feel my stroke’. Athletes in other sports will also talk about not ‘feeling right’. This concept of ‘feel’ is related to neural (nervous system) fatigue and it is a good indicator of overtraining and excessive fatigue
- . stress — athletes are subject to all the stresses and strains of life including those surrounding family, study, relationships, money and work. There is a strong relationship between life stress and fatigue levels. In young athletes it is essential to consider the planning of the training program in relation to school and exam loads, particularly for teenage students completing final high school exams.

These fatigue factors are simple to monitor and measure and can be excellent indicators of training adaptation. It is essential that coaches manage the overall training loads that athletes experience individually and keep in mind the demands of all training and competition activities as well as outside-of-sport demands when developing training and recovery programs.

Case study

Lars is a successful European handball coach who decides to introduce a strength training program for the first time. The club has given him a budget and he is able to purchase a range of suitable equipment and also to enlist the help of a strength expert recommended to him by another coach. Lars schedules the gym program opposite the running program. During training cycles where the athletes worked hard on the running program, the gym program was relatively light and easy, and when the gym program was hard then the running work was more relaxed. It seemed like a great plan, but the team’s season ended up being one of their worst ever.

Work is work. The mistake Lars made was to swap one form of work (training) for another (strength training) without really providing the athletes with a chance to rest and recover.

Reversibility

If you don’t use it, you lose it! If an athlete stops training a particular physical capacity by either reducing the training load or by stopping the activity altogether, the fitness levels they have gained will be lost. Although no one is really certain why, the body seems to remember how to move, train and compete even if it has not done a specific activity for some time. For example, if it takes five years for a gymnast to learn how to perform a complex routine and injury forces

them out of training for six months, leading to a loss of strength, fitness and skill, it takes significantly less than six months for the athlete to return to pre-injury performance levels.

Aerobic endurance can be lost relatively quickly, and it is important that athletes maintain a base level of endurance during off-season periods or breaks in regular training due to injury. A football player, for example, might engage in regular cycling or swimming for fitness during the summer off-season period. A swimmer may take up open water or surf swimming during a break from pool training to maintain aerobic fitness.

Variety

As well as being effective, training and competition activities should be varied, interesting, stimulating and enjoyable. Coaches might consider changing training locations or training times and days, introducing new training equipment or changing the frequency, intensity and volume mix. Regularly introducing new exercises also serves to offer variety, which maintains interest and challenges muscles and systems, forcing them to adapt with increased size, strength and/or efficiency.

Case study

Karen is a dedicated hockey coach who has been coaching under-14 hockey players for ten years. She always spends a great deal of time carefully planning and preparing her sessions and is a regular at the professional development sessions at her club. Lately she has been concerned that, although the players work hard at training, they do not seem to really enjoy her sessions. Disappointingly, their match performance has not really been what she had hoped either. The fitness development sessions on Tuesdays seemed to be a particular problem.

Karen knows a good base of general fitness is important, but she also knows that what she is doing at present is not working. On reflection she decides that while she has included all the key elements needed in a fitness program, the sessions lack variety. Karen decides to include the team in preparing the Tuesday sessions. She outlines on the whiteboard four key elements for them to consider in their planning. The session should be 30 minutes long and must include 20 minutes of non-stop, continuous movement with limited rest at low intensity.

The session must include 20 short (around 20 metre) all-out sprints and 50 body-weight resistance exercises such as push-ups, pull-ups, steps-ups and dips.

The response from the athletes is great. They love planning their own sessions and decide to run their fitness sessions down by the river, a short walk from where they usually train. The

team also comes up with some great ideas about how to include the necessary elements in a series of fun sessions. They even allocated two different players each week to actually run the sessions and to ensure that everything is done.

They mixed things up in ways Karen had not even thought of. Not only did this approach offer variety in training, which is important for developing their physical attributes, but at this age the players were really keen to take some responsibility for their development and have stronger ownership of their team. Planning their own sessions offered them this opportunity and gave them a good sense of being part of the team as a whole.

Specificity

You get what you train for. Training activities and programs must be closely related to performance goals. To perform with increased strength, training loads need to emphasise increased strength development through gym work or resistance training. To perform with increased endurance, training loads need to emphasise increased endurance development through long-distance running, cycling, swimming or cross country skiing.

Remember, the most specific training of all is to simply play the sport.

Individuality

Each individual will adapt to training and competition loads differently based on genetic, behavioural, environmental and developmental variations. Swimmers competing in the same event may require different amounts of training and a different mix of training elements. Players playing in the same team may require different training loads and recovery activities even though they play in the same position.

Individualising training programs in team sports is one of the great challenges for team-sport coaches. In some sports, players are grouped together based on their on-field positions for tactical reasons and not necessarily based on their physical capacities or recovery abilities. Wherever possible, each athlete should be given an individualised training program to ensure optimal adaptation and performance potential. Each athlete's ability to adapt to training and competition loads depends on a variety of factors including:

- . genetics
- . training background and history
- . gender

- . outside of sport commitments such as school, family or work
- . injury status.

Case study

Peter is a 34-year-old triathlete who has been involved in the sport for two years. He became involved in triathlon to keep fit and stay healthy after a long career in lacrosse. Peter regularly trains with a large group of triathletes, all around his age. Even though Peter does all his training with the group and completes the same training programs, he finds he is not competitive with many of the group when they race, particularly in the swimming and cycling legs. He decides to raise his concern with his coach, Theo.

Theo suggests that as Peter's sporting career has until now been largely based on running, he should focus on developing skill, technique and knowledge of swimming and cycling. They make a simple but important change to Peter's training program by decreasing the amount of running, adding an extra swimming session each week with a specialist swim coach and also an additional cycling time trial where Peter trains alone, focusing specifically on learning how to cycle more efficiently at high intensity.

Summary

Simplicity is the key. An educated athlete with a strong feel for training load and an understanding of how their body works, training together with an educated coach who has an understanding of, and empathy for, their athlete as well as an understanding of the principles of sports science, can achieve great things. While sports physiology can provide coaches and athletes with technology and tools to measure a wide range of responses and adaptations, often it comes down to what is practical, simple, affordable and immediately available.

Just as a smart investor does not put all their eggs in one basket, coaches and athletes should not place all their faith in one particular physiological measure or technique. The most effective training methodologies lie in a unique combination of both the art and science of coaching and an educated 'feel' for the individual athlete.

References and further reading

Fleck, SJ and Kraemer, WJ 2004, *Designing Resistance Training Programs*, 3rd edn, Human Kinetics, Champaign, Illinois.

Gore CJ (ed.) 2000, *Physiological Tests for Elite Athletes*, Human Kinetics, Champaign, Illinois.

Hoffman, J 2002, *Physiological Aspects of Sport Training and Performance*, Human Kinetics, Champaign, Illinois.

Sharkey, BJ and Steven, EG 2006, *Sport Physiology for Coaches*, Human Kinetics, Champaign, Illinois.

Wilmore, JH and Costill, DL 2004, *Physiology of Sport and Exercise*, 3rd edn, Human Kinetics, Champaign, Illinois.