Sports science

Sport and exercise scientist Victoria Penpraze explains what sports science is all about

What makes Usain Bolt the fastest human over 100 m? Is there something about his muscle fibres that enable him to sprint faster than anyone else? How is Jessica Ennis-Hill able to perform at a world-beating standard in seven different disciplines? How can Andy Murray withstand the pressure to play championship-winning tennis on Wimbledon's centre court? How have they become so mentally and physically tough? If these questions interest you, then sports science could be for you.

Key words

Energy
Muscle
Red blood cell
$\dot{V}O_2$ max
Marginal gains

Sports science is the study and application of scientific principles with a view to improving athletic performance at all levels of sport. It is a multi-disciplinary science with three main branches: physiology, psychology and biomechanics. Sport scientists research, and apply their understanding of that research, to help coaches and athletes plan the most effective training programmes for competition requirements (see Box 1). The main objectives are to maximise recovery strategies, improve technique, reduce injury risk and aid a successful return to sport after injury, help athletes excel under physiological and psychological pressure, cope with adversity and increase the longevity of their athletic career.

Physiology

Sports physiology investigates how the body responds to training and competition (see Figure 1). Athletes often perform in different environmental conditions and so their responses are investigated in these environments. For example, at altitude, where the partial pressure of oxygen is lower, there is less oxygen available to breathe in, bind with haemoglobin and thus less transported in the blood to the working muscles (reduced oxygen saturation). The hypoxia (lower than normal levels of oxygen in the blood) also stimulates increased respiration and increased cardiac output for a given work rate and can thus reduce an athlete's ability to train. If athletes go

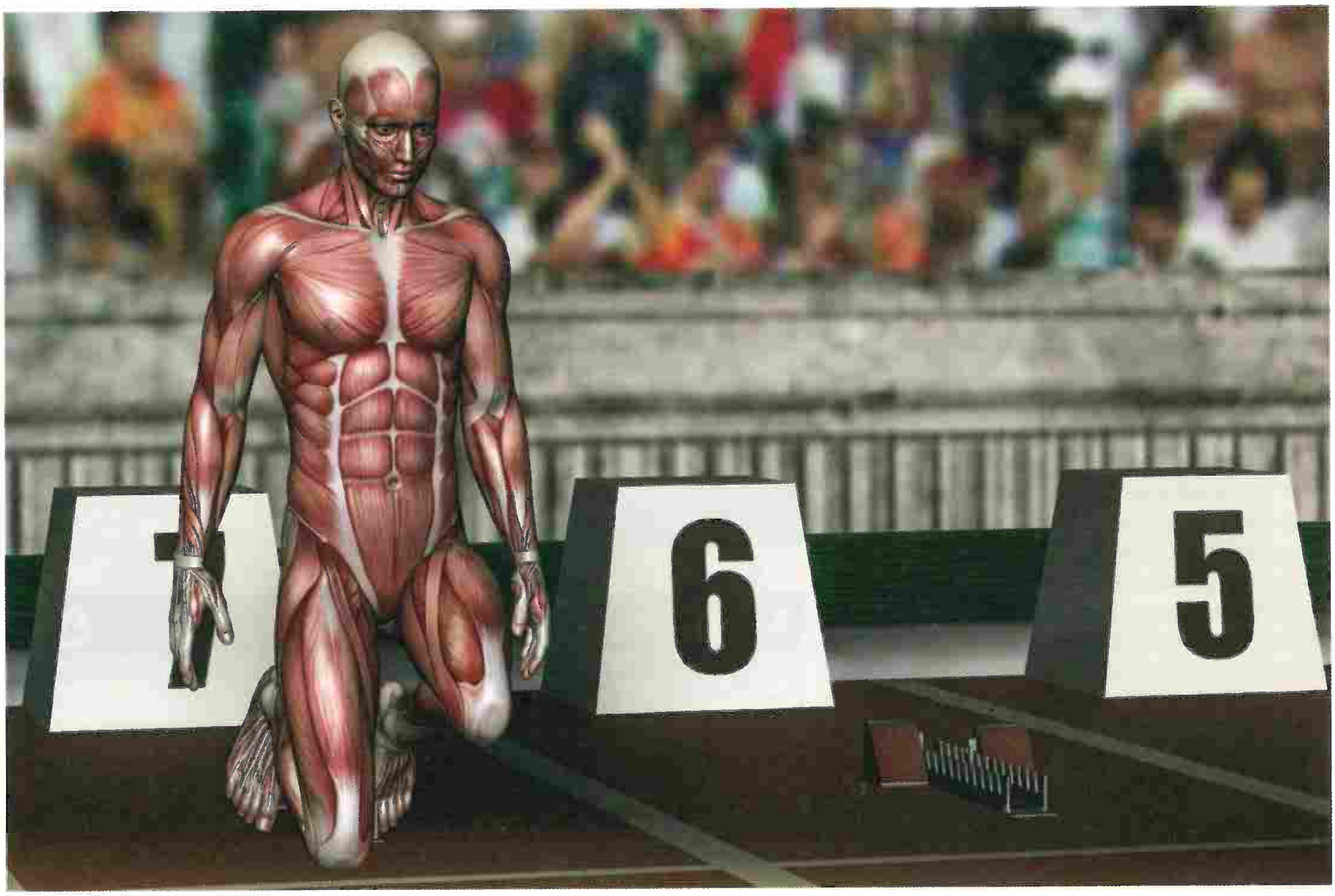


Figure 1 (a) An athlete completing a $\dot{V}O_2$ max and lactate test on a treadmill. **(b)** Examining the effects of extreme temperature on performance in an environmental chamber where temperature and humidity can be manipulated

to high altitude for a period of time and descend to train (also known as 'live high, train low'), physiological adaptations take place so that they are better able to cope with hypoxia. In this case, endogenous **erythropoietin** (EPO) increases, which stimulates an increase in red blood cells and thus increases the oxygen-carrying capacity of the blood.

Hot and humid climates are also of interest. It is important to prevent a rise in core temperature and in hot environments this is done by dissipating heat through capillary vasodilation, which increases blood flow at the skin, allowing some cooling by evaporation. Increased sweat rates also occur, which can lead to loss of total body water and electrolytes. Athletes can become hypovolemic (lower than normal blood volume), which may quicken time to fatigue. Pre-cooling of the body and appropriate fluid replacement can reduce the effects of heat.

Physiologists are interested in an athlete's ventilatory, cardiovascular, neuromuscular and metabolic responses — how these may change with training and what limits performance. Physiologists have researched these features extensively to work out how they can be manipulated and thus allow further performance improvement. One of the most widely investigated **determinants of performance** is $\dot{V}O_2$ max (the maximum rate that your muscles can extract and use oxygen from your blood; see Figure 1). Another is lactate threshold (LT; the work rate at which the amount of lactate in the blood exceeds its clearance or buffering). Lactate is produced in the skeletal muscle cells when pyruvate (from glucose breakdown) 'mops up' the hydrogen ions (from another energy-giving process in cell metabolism). Lactate can accumulate in the blood as a result of **anaerobic metabolism** during high-intensity exercise. It is a good 'indirect' marker for the metabolic state of the muscle. Another

Box 1 The aggregation of marginal gains

Sir Dave Brailsford, former Performance Director for British Cycling, has a systematic and scientific approach to better athletic performance. He strives to examine each and every aspect that can affect performance and find a way to improve it, even by just 1%. Adding up all the 1% improvements can make a big improvement overall. To achieve this, he assembled a multi-disciplinary team of top sports scientists from different areas of expertise. This included experts in physiology, psychology, biomechanics, **ergonomics** and nutrition. Cycling's success is testimony to the effectiveness of his approach.

Dr Matt Parker, Head of Athletic Performance for England Rugby and formerly Head of Marginal Gains at British Cycling/Team Sky, knows well the importance of sports science. He says, 'Athletes may only have one shot to fulfil their dream and the margins between winning and losing are often very small. There is a responsibility to ensure you're doing your job to the highest possible standards.'

Small margins can be critical to an athlete's success. In the 2013 World Championships, Christine Ohuruogu won the 400 m in a time of 49.404 s, beating her rival by 0.004 seconds.

Terms explained

Anaerobic metabolism Energy-providing process in the cell that can occur in the absence of oxygen. **Aerobic metabolism** involves energy-providing processes in the presence of oxygen.
Determinants of performance Factors that influence sporting or competitive ability.
Ergonomics The study of a person's efficiency of movement and performance in their sporting environment.
Erythropoietin (EPO) A hormone produced by the kidneys.

Figure 2 Biomarkers on an athlete

determinant is critical power — the maximum power that can be sustained over a prolonged period of time (see Box 2).

Biomechanics

Biomechanics is the study of the mechanics of human movements and how athletes interact with their apparatus through the application of mechanical principles. Measurement methods include two-dimensional/three-dimensional video-analysis and electromyography (EMG), which measures the electrical activity in muscles. Most commonly, reflective markers are placed on specific points on the body and detected by fixed cameras in a laboratory (see Figure 2), which produces a 'stick image' of body movements. This strategy allows biomechanists to identify the best technique for enhancing performance. For example, this can be used to help high-jumpers by examining the forces acting through the body and the geometry of the body in the run-up, jump off and flight over the bar.

Biomechanists can help determine the most effective ways of performing a specific sporting skill. Plates built into the laboratory floor can record the forces experienced through the leading leg of a fast bowler in cricket when their front foot hits the ground while whipping the arm through to release a fast ball. Training can be implemented to ensure that this contact doesn't cause injury. If you play golf, you may have analysed your swing in a driving range video booth. Biomechanists also analyse sports equipment such as shoes, racquets and playing surfaces.

Psychology

Sport psychology is the identification and understanding of psychological theories and techniques that are applied to sport to enhance the personal development and performance of athletes (see Box 3). It attempts to explain how motivations, beliefs and emotions influence sporting behaviour. Areas of research interest include athletes' mental preparation for sport. This includes mental toughness, paying attention to the appropriate cues for performance, ensuring athletes achieve their optimal level of arousal for performance, developing leadership, managing aggression and helping athletes set goals. Cognitive–behavioural interventions (CBI) are training programmes for the mind and help athletes develop these important psychological skills.

A visible application of sport psychology is watching a rugby player prepare to execute a penalty or conversion kick. Owen Farrell (England)

Box 2 $\dot{V}O_2$ max, lactate threshold and critical power

Concepts such as $\dot{V}O_2$ max, lactate threshold and critical power can be used to determine fitness and test effectiveness of training programmes.

$\dot{V}O_2$ max can be determined from an exercise test where the workload is progressively increased until the exerciser reaches exhaustion and cannot continue. As the test progresses, the amount of oxygen used increases until the person is unable to use any more. This is seen in Figure 2.1 for trained and untrained exercisers. The question of what limits $\dot{V}O_2$ max is hotly discussed. Some sports scientists suggest it is limited by factors related to muscles, some say it is the cardiopulmonary system and others argue it is limited centrally by the brain.

Lactate threshold (LT) is determined by analysing the lactate concentration in small 'pin-prick' blood samples taken from the exerciser at regular intervals during an exercise test. In an untrained person (see Figure 2.2) LT occurs at a lower work rate (blue arrow) than when trained (green arrow). Training ensures physiological adaptations to delay the point at which lactate accumulates in the blood, for example by increasing the number of mitochondria, which can improve the muscle's ability to extract and use oxygen.

What is critical power and how is it useful for sports scientists and athletes? View this YouTube clip by Dr Philip Skiba: www.youtube.com/watch?v=86Sw3vOCq9U

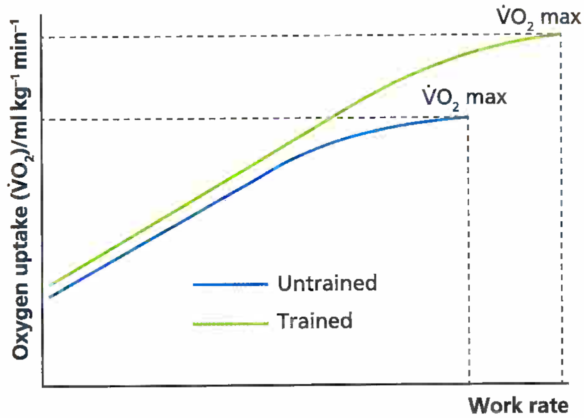


Figure 2.1 Oxygen uptake with increasing work rate in the untrained and trained exerciser

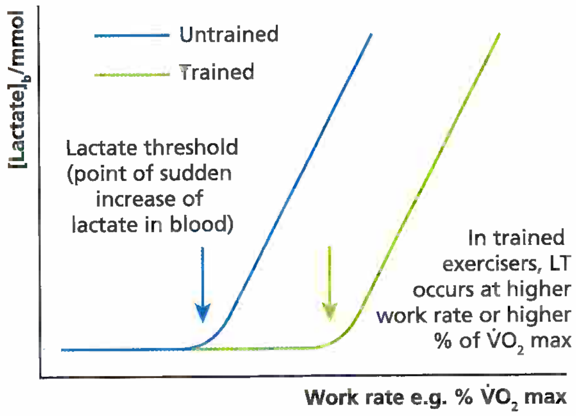


Figure 2.2 Lactate concentration in the blood with increasing work rate in the untrained and trained exerciser

and Jonny Sexton (Ireland) complete a pre-shot routine before they execute the skill (see **www.youtube.com/watch?v=0JGBJcvpiKg**). Psychological pressure can increase muscle tension, which may cause them to pull the kick wide. If their focus is disrupted they may start to think 'what if I don't score?' The pre-shot routine allows them to focus on task-relevant cues — to visualise a successful kick and be relaxed. Did you spot Farrell's visualisation phase in the YouTube clip? A pre-shot routine is the same set of steps, takes the same length of time to perform and is completed exactly the same every time before the skill is executed and creates a familiar environment for the athlete.

Working with the world's best

Sports scientists work with the world's best athletes, with associated high costs, high risks and high rewards.

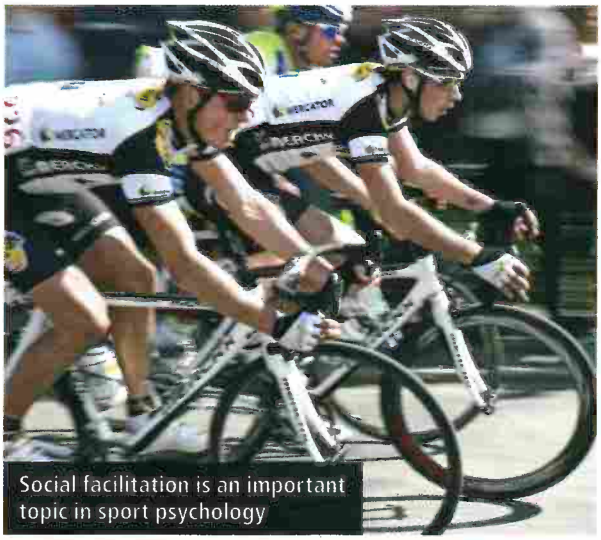
The UK's recent sporting renaissance has increased expectations of better performance, and sports science has played an important part. Team GB athletes often include #BetterNeverStops when tweeting about their rigorous training.

Box 3 Early experiments in sport psychology

Norman Triplett (1861–1931) is credited as the first person to link sport and psychology. His ground-breaking cycling experiments in 1898 investigated how other competitors affect cycling performance. Triplett compared cycling race times under three different conditions:

1 no pacing, no competitors
2 paced by trained colleagues, no competitors present
3 paced and with competitors

His graph (see Further reading) shows that the time taken for each mile cycled is shorter when there are other competitors present. The athlete performed the slowest, at any mile point measured, when there was no pacing nor competitors present. Triplett was convinced the reason was not physiological nor mechanical, but psychological. He said that the presence of competitors served to 'liberate latent energy not ordinarily available'. The concept of 'social facilitation' was born and is still important today.



Social facilitation is an important topic in sport psychology

Further reading

British Association of Sport and Exercise Science: **www.bases.org.uk**
European College of Sports Sciences: **www.ecss.de**
The European Federation of Sport Psychology: **www.fepsac.eu**
SPORTSCIENCE: **www.sportsci.org**
Triplett, N. (1898) 'The dynamogenic factors in pacemaking and competition', *American Journal of Psychology*, Vol. 9, pp. 507–533.

Dr Barry Fudge is head of sport science for British Athletics. He provides sports science support to Mo Farah, including his Olympic gold medal performances. Dr Fudge says, 'working in elite sport is incredibly exciting' and also recognises the difficulties: '...it's a tough environment at times, high stakes and high expectations'.

Dr Laura Forrest, exercise physiologist, adds that '... seeing a research-driven idea impacting on performance is an exciting area of applied sports science'.

According to Dr Matt Parker (see Box 1), sports science input is 'the scientific process [that] underpins the development of performance plans. Better performances are puzzles that are solved through appropriate questioning, application of current knowledge and continued search for knowledge'.

Being a sports scientist requires many different skills. Dr Fudge says, '...you use the analytical part of your brain. Decision making, problem solving, testing interpretation all require a scientific mind.' He believes the discipline is still developing and proposes, '...the biggest breakthrough in sport science will come from genetic research that can provide individualised support (e.g. physiology, nutrition, psychology etc.)'

Studying sports science at university

Being good at sport is not a pre-requisite for studying sports science or a related degree. Having an interest in biological sciences is very useful. These courses are scientific and multi-disciplinary. Many UK undergraduate degrees are available and often called 'sport *and* exercise science' programmes where students also learn about the body's physiological and psychological responses to exercise, physical activity or being sedentary, and their effect on health.

Programmes related to sport and exercise science include:

- sports medicine — a branch of medicine related to the health, well-being and quality of life of athletes
- sports nutrition — investigating optimal energy intake and hydration levels for sport

Dr Parker envisages a bright future: 'Sports science is established as a fundamental component of sustained success in sport [and] there will be continued progression...'. This requires new sports scientists to develop the discipline for years to come. This could be you.

Victoria Penpraze is course coordinator for physiology and sports science at the University of Glasgow. Her teaching and research interests include exercise and sport psychology, factors affecting sport performance and children's physical activity.