SECTION 28 Sport and exercise Section editor John

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ESSENTIALS Physical activity through sport can promote health and well-being but can result in injury, illness, or both. Understanding the patient, their ideas, expectations and concerns, their sporting goals, sporting level, psychology and past history is essential to ensuring adherence to any management programme. The scope of sport and exercise medicine includes (1) injuries, including those impacting bone health; (2) illness in and caused by sport, ranging from sudden cardiac death to overtraining syndromes and exertional heat illnesses; (3) drugs in sport and doping—all high- performance athletes and associated staff need to be educated about the World Anti-Doping Association code, the dangers of doping, and testing protocols; and (4) exercise as medicine, which is an important part of most disease prevention and management strategies. Introduction Sport and exercise medicine is an area of medicine that has its origins in Greco-Roman times (5th century bc) when Herodicus, the teacher of Hippocrates, became the first physician to recom- mend exercise for the management of disease. Subsequently, Galen (2nd century ad) became the first ‘team physician’, being respon- sible for the care of gladiators. In modern times, an understanding of sport and exercise medicine is of relevance to most clinical specialties. Physical ac- tivity through sport can promote health and well-being but can result in injury, illness, or both, that may present in a variety of settings. Furthermore, individuals with chronic diseases may participate in sport at a high level, influencing disease manage- ment. Perhaps most importantly, the use of exercise as medicine is an important part of most disease prevention and management strategies. This chapter provides a brief insight into injury and illness in sport. Challenges in medical management of the high-performance athlete are discussed. Finally, a concise review of exercise as medi- cine is provided. General principles of sports medicine The medical management of an athlete should follow the principle of ‘Know your patient, know their sport, and know their injury/illness’. Understanding the patient, their ideas, expectations, and con- cerns, their sporting goals, sporting level, psychology, and past history is essential to ensuring adherence to any management pro- gramme. The ‘athletic psyche’ is one that is highly focused and often there is high patient anxiety associated with an injury or illness. Hence, successful management of medical issues requires an under- standing of this to promote adherence to any alterations in training programmes, and relative rest where needed. The physiological, physical, and psychological attributes of high- performance athletes can be extraordinary and medical

assess- ment must take a different ‘norm’ into consideration. For example, athletes from endurance sports typically have oxygen uptakes of 85 ml/kg per min (versus 50 ml/kg per min in a good club ath- lete), and elite rowers can have a lung capacity in excess of 11 litres (normal capacity is 6 litres). Intensive training (and perhaps gen- etics) can result in alterations in normal serum markers commonly assessed in the clinical setting. For example, total, muscle, and car- diac creatine kinase concentrations can all be significantly elevated in a healthy athlete. Training can result in raised levels of serum aspartate aminotransferase from muscle, alanine aminotransferase mainly from the liver, and bilirubin due to haemolysis. Creatinine levels may be elevated due to an athlete’s high muscle mass and pro- tein intake and not necessarily indicate a reduction in glomerular filtration rate. The pressures of competitive sport and negative influences of those surrounding high-performance athletes mean that at times the role of the physician is one of a medical guardian, protecting the health and well-being of the athlete against all other agendas. Injuries in sport Epidemiology Sports injuries can be described as acute, chronic overuse, or acute on chronic. Their incidence is unknown since epidemiological 28.1 Sport and exercise medicine Cathy Speed

Section 28 Sport and exercise medicine 6566 studies are difficult and tend to focus on specific injuries and/or specific sports in defined groups, but data related to the London Olympics in 2012 are shown in Fig. 28.1.1. Injuries to soft tissue are most common, some of which also in- volve intra-articular damage leading to early-onset osteoarthritis. Approximately 85 000 sport-related fractures occur every year in the United Kingdom, representing approximately 13% of total frac- tures. There is now heightened awareness of the incidence and con- sequences of head injuries in sport and concussion guidelines are now well established. Diagnosis The mechanics of the sport influences the types of injury seen and the challenges in returning the patient to training and competition. Certain extrinsic and intrinsic factors are known to predispose individuals to injury (Table 28.1.1). It is important to recognize that athletes often have asymmetrical development (e.g. a tennis player) and different ranges of motion (e.g. a gymnast); what is ‘normal’ for an athlete often differs significantly from the general population. In addition to these general risks, certain factors are associated with an increased incidence of specific injuries. For example, fe- males have a significantly higher risk of anterior cruciate ligament injuries of the knee, and children and adolescents are at increased risk of avulsion and growth plate injuries. Older athletes have an in- creased susceptibility to soft tissue injuries and arthritis, have higher rates of comorbidities that may influence the injury, and are slower to respond to treatment. History Evaluation starts with taking a history of the injury and its mech- anism as this helps to form a differential diagnosis. Consider extrinsic factors including training and competing behaviours, pre- vious injuries, and medical history. Note the remote possibility of an underlying tumour or disease such as inflammatory arthritis. Pain is usually the presenting symptom. Its character, site(s), radiation, timing, and relieving/aggravating factors should be evaluated. Note any neurological symptoms. The treatments used to date, medication, and supplement history should be established. Football Taekwando Diving Basketball Cycling road Wrestling Boxing Modern pentathlon Volleyball Beach volleyball 0 2 4 6 8 10 12 14 Synchronized swimming Tennis Table tennis Fencing Badminton Total Water polo Gymnastics Judo Hockey Athletics Triathlon Weightlifting Handball Cycling BMX Cycling MTB

7 days 1 day Fig. 28.1.1 Percentage of athletes (horizontal axis) affected by injuries in specific sports leading to time loss (≥1 or >7 days) of competition and training at the Summer Olympics, London, 2012. Sports not listed reported less than 2% of athletes were affected. MTB, mountain bike. Table 28.1.1 Factors predisposing to injury in sport Intrinsic Extrinsic Previous injury Training: too much, too soon, too often Presence of another injury Technique Movement kinematics Equipment Muscle weakness/imbalance Surface Hypermobility Environment Poor flexibility (local, general) Drugs (e.g. anabolic/corticosteroids) Femoral anteversion Poor nutrition Tibia varum/valgum Aggressive play Pes planus/cavus Chronic diseases
(e.g. rheumatoid arthritis)

28.1 Sport and exercise medicine 6567 The extent of swelling and its speed of onset typically correlate with the severity of injury. Joint instability suggests structural damage or may be related to pain. Examination The initial examination seeks signs of other disease, evidence of intrinsic risk factors, and includes spinal assessment. Functional movement, stability, and core control are important. Assessment for asymmetry of muscle development and flexibility are important but must be interpreted carefully. Regional assessment of the injury follows the usual strategy of ‘look, feel, move, and special tests’. Identification of the site(s) of swelling, tenderness, instability, and neurovascular status follows. Dynamic assessment is often necessary to reproduce symptoms that may only be present during activity. Investigations Imaging studies are useful in the assessment of an injury but should be utilized only after a clinical diagnosis has been made, and when the information gained will assist in management. Imaging findings must be interpreted with caution since many athletic individuals will have structural abnormalities noted that are coincidental. Radiography, diagnostic ultrasonography, MRI, CT, and isotope bone scans are all used. Plain radiography is insensitive to many bone stress injuries but is used to assess for fractures, loose bodies, myositis ossificans, and significant arthritic change. Diagnostic ultrasonography is often utilized by the clinician during the initial assessment, allowing detailed dynamic assessment of soft tissue pathologies. MRI provides information on soft tissue and bony structures, and bone oedema syndromes. Magnetic resonance arthrography may be necessary to demonstrate intra-articular path- ologies and in particular labral tears of the hip and shoulder. The main use of CT is to assess bone healing and to detect loose bodies. Single-photon emission CT may be used to evaluate some bone stress injuries, particularly those affecting the pars intra-articularis. Further assessment of bone health is discussed in ‘Bone health in athletes’. Compartment pressure studies identify those individuals with chronic exertional compartment syndromes. Serology for under lying medical complaints may be necessary. Management Successful management of sports injuries necessitates an accurate diagnosis and identification of all contributing factors. Patient ad- herence with any treatment programme comes through athlete education about the injury, its implications for training and compe- tition, and best management. Clear goals are set and reviewed regu- larly. The athlete must always feel supported through this process. Effective pain management allows rehabilitation to proceed. In the acute injury, the classical PRICE regime (protect, rest, ice, compression (if necessary), elevation) is followed. Rest is relative; training is continued to maintain fitness while not stressing injured areas. Supports are used to facilitate this in some injuries (e.g. ankle sprains). Rehabilitation is the foundation stone of management of most sport-related injury.

Restoring function of the injured area through controlled loading programmes and addressing those inherent risk factors that may predispose the athlete to injury are all addressed. Any rehabilitation programme progresses through simple strength- ening and flexibility work through to sport-specific activities. Medications and injections are used judiciously to reduce exces- sive inflammation and to control pain in order to allow rehabili- tation to proceed. Oral nonsteroidal anti-inflammatory drugs can be used inappropriately by athletes and can slow bone and soft tissue healing. Topical agents are preferred. Injections including platelet-rich plasma and viscosupplement injections may be used for some injuries, but evidence of their efficacy is limited. The use of steroid injections is generally discouraged due to the atrophic effects on tissue. Return to play takes place only when the athlete is both physic- ally and psychologically ready. The athlete must demonstrate the ability to perform sport-specific functional tasks without conse- quences. Psychological factors, typically anxiety and depression, can influence recovery. There must be trust and rapport between the athlete, physician, and support team throughout the recovery process. Psychological readiness to return to play must be con- firmed by the athlete and medical team. Surgery is necessary in few cases. Indications include fractures, joint disruption, some meniscal tears, acute traumatic tendon rup- tures, and compartment syndromes. A period of 'prehabilitation' may precede operative treatment. Bone health in athletes In most individuals, physical activity is good for bone health, but energy deficiency and hypothalamic hypogonadism result in sig- nificant negative consequences on bone in some athletes. This is known as the (female) athlete triad, typically seen in females but increasingly recognized in males. Participants in endurance or lightweight sports, or both, are particularly affected. Lack of en- ergy availability can be related to intentional or unintentional undereating, with most effects appearing to occur below an energy availability of 30 kcal/kg of fat-free mass per day. Heavy intensive physical training and energy deficiency results in leptin deficiency and hypogonadal hypogonadism. Hypogonadism can be subtle: only a minority of females are amenorrhoeic; oligomenorrhoea and anovulation are common, but some susceptible athletes are eumenorrhoeic. Those who are amenorrhoeic should be investigated for other causes, and medical causes of low body weight (malabsorption syndromes, endocrine causes, etc.) should also always be considered. Investigations in those with the triad are often normal but may show evidence of nu- tritional deficiencies or changes typical of anorexia. An ECG should be obtained, as arrhythmias and long QT syndrome can occur, even in the absence of electrolyte abnormalities. In any athlete where a low bone mass is suspected, a dual-energy X-ray absorptiometry scan is performed, including posteroanterior lumbar spine and hip (femoral neck and total hip). In those less than 20 years of age, posteroanterior spine and whole body are pre- ferred sites. The scan must be interpreted carefully; there is no bone mineral density (BMD) threshold that strongly predicts fractures in young people. Athletes in weight-bearing sports typically have a BMD 10 to 15% higher than normal, hence a Z score less than −1.0 indicates bone health impairment. Even those with a normal BMD level can sustain fragility injuries due to impaired bone health. In those with ongoing triad symptoms or reduced BMD, or both, dual energy X-ray absorptiometry scanning should be repeated annually.

 The health consequences of the triad can be significant. Cardiovascular, renal, metabolic, endocrine, reproductive, neuro- logical, and psychological complications of energy deficit and hypo- gonadism can occur. There are negative effects on bone health, and recurrent fragility (i.e. occurring below the expected mechanical threshold) bone and soft tissue injuries are common. Management of athletes with the triad is

challenging and re- quires a multidisciplinary team approach. The athlete’s support team (coaches, physiotherapist, etc.) must all be attentive to those at potential risk. Input from a mental health team and dietician is often needed. Athletes should not be permitted to continue to train without reaching specific health-related goals. Illness in sport Illness is common in sport. Data related to the London Olympics in 2012 are shown in Fig. 28.1.2. Cardiovascular issues: sudden cardiac death Sudden cardiac death in athletes is a rare but well-recognized event. Young athletes are reported to be at a 2.8-fold risk of sudden cardiac death compared to nonathletes. In middle-aged and older adults, underlying cardiovascular disease is the most common cause. In younger athletes, there several causes which manifest under the circumstances of strenuous exercise (Table 28.1.2). Screening for these conditions in young high-performance athletes is rou- tinely performed in many sports but is challenging, as not only can it be difficult to differentiate between physiological adaptations and cardiomyopathic processes, but some causes are not detected by screening. The interpretation of investigations is considered the remit of a sports cardiologist (Fig. 28.1.3 and Table 28.1.3). Screening programmes to date do not appear to have influenced the incidence of sudden cardiac death. Airway health Respiratory symptoms are common in elite athletes, who are at higher risk of airways dysfunction. Indeed, bronchial hyperresponsiveness/ asthma is the most common chronic medical condition experienced by both summer and winter Olympians. Bronchial hyperresponsiveness is defined as a positive bron- chial provocation test to a physical stimulus (i.e. exercise, dry air hyperpnoea, or hyperosmolar aerosols) or to a pharmacological stimulus (i.e. inhaled methacholine or histamine). High ventila- tion rates during exercise, airway dehydration, cold air, allergens, and pollutants can all contribute to airway epithelial injury, which then may result in bronchial hyperresponsiveness/asthma. Atopy and the type of training are also significant risk factors. Asthma is 25 times more likely in atopic sprint athletes and 75 times more likely in atopic endurance athletes, compared to nonatopic ath- letes. Strategies to control and reduce these triggers are vital, but challenging. Canoe slalom Shooting Volleyball 0 2 6 4 8 10 14 12 18 16 20 Total Swimming Rowing Archery Cycling track Sailing Football Taekwando Diving Basketball Cycling road Wrestling Boxing Modern pentathlon Beach volleyball Synchronized swimming Tennis Table tennis Fencing Equestrian Canoe sprint Badminton Water polo Gymnastics Judo Hockey Athletics Triathlon Weightlifting Handball Cycling BMX Cycling MTB Fig. 28.1.2 The percentage of athletes (horizontal axis) affected by illnesses in specific sports leading to time loss from competition and training during the Summer Olympics, London, 2012.

 Athletes are screened and diagnosed according to objective test re- sults. The eucapnic voluntary hyperventilation challenge test is cur- rently the preferred laboratory test for bronchial hyperresponsiveness in athletes, with a reduction in FEV1 post challenge of at least 10% indicating a positive test. Limiting environmental and other triggers to airways injury should be addressed where possible. Pharmacological treatment is similar to that in nonathletes. Inhaled corticosteroids are the most effective drugs for long-term control of asthma and prevention of bronchial hyperresponsiveness. Inhaled β2-agonists are not performance enhancing and are no longer banned within likely normal therapeutic dose ranges. Some treatments, for example, oral steroids in acute severe asthma, still require a Therapeutic Use Exemption certificate. The clinician must always seek up-to-date information as guidance by the World Anti- Doping Association (WADA) on permitted medications changes regularly. Upper airways dysfunction is also common, with causes includ ing laryngeal obstruction (typically due to psychogenic, irritant- induced, or reflux-related vocal cord dysfunction), nonspecific cough, and rhinitis. Symptoms suggestive of upper respiratory tract infection are also common but infection is

present only in one-third and many cases can be attributed to other inflammatory stimuli associated with exercise. Diabetes in sport There are an increasing number of diabetic patients taking part in competitive sport. The physiological demands of strenuous training, the stress of competition, and at times unpredictable timing of meals can make glucose homeostasis challenging. Most young athletes with diabetes have type 1 diabetes and are at risk of hypo- and hyper- glycaemic episodes and ketosis. It is necessary to educate the athlete and support staff to monitor blood glucose before exercise, every 30 min during exercise, and at 2 and 4 h post exercise, and to optimize their recognition of hypoglycaemia and its management. The athlete is safe to par- ticipate if the blood glucose level is in the range 100 to 250 mg/dl (5.6–13.9 mmol/litre) (preferably 180 mg/dl, 10 mmol/litre). If the glucose concentration is less than 100 mg/dl (5.6 mmol/litre), the athlete supplements with carbohydrate and if greater than 180 mg/ dl (10 mmol/litre), he/she hydrates with a noncarbohydrate drink Table 28.1.2 Common causes of sudden cardiac death in young athletes (<35 years old) Structural cardiac abnormalities Electrical cardiac abnormalities Acquired cardiac abnormalities Hypertrophic cardiomyopathy Arrhythmogenic right ventricular cardiomyopathy Marfan's syndrome Mitral valve prolapse/aortic stenosis Wolff–Parkinson–White syndrome Congenital long QT syndrome, Brugada syndrome Catecholaminergic ventricular tachycardia Myocarditis Trauma (commotio cordis) Toxicity (drugs) Hyper/hypothermia

- RV dilatation
- Asymptomatic
- Isolated voltage criteria for LVH on ECG
- LV dilatation (>55cm) with preserved LV function
- Normal RV function
- Symptoms ± family history
- Symptoms ± family history
- Pathological Q waves, ST-segment depression, LBBB or T-wave inversion in inferior/lateral leads
- ASH, LV cavity <45mm, LA enlargement & abnormal diastolic filling
- Peak VO2 max <50ml/kg/min on CPET
- CMR: delayed gadolinium enhancement
- T-wave inversion beyond V2 ± Epsilon waves on ECG ARRHYTHMOGENIC RIGHT VENTRICULAR CARDIOMYOPATHY ATHLETE'S HEART HYPERTROPHIC CARDIOMYOPATHY
- Impaired RV function ± impaired LV function
- VT documented on 24-hour tape/ETT
- Incomplete RBBB
- Ventricular extra-systoles of LBBB morphology
- 'Grey zone' of LV wall thickness of 13–15mm
- T-wave inversion V1-V2 Fig. 28.1.3 Differentiating between physiology and pathology: the 'athlete's heart' versus hypertrophic cardiomyopathy (HCM) and arrhythmogenic right ventricular cardiomyopathy (ARVC). Regular exercise can lead to physiological adaptation of cardiac structure and function (athlete's heart) which can be identified by changes on ECG and echocardiography. There is some overlap with HCM and ARVC (yellow arrows). Key features can be used to differentiate between physiology and pathology. ASH, asymmetrical septal hypertrophy; CMR, cardiac magnetic resonance imaging; CPET, cardiopulmonary exercise test; ETT, exercise tolerance test; LBBB, left bundle branch

block; LV, left ventricular; LVH, left ventricular hypertrophy; RBBB, right bundle branch block; RV, right ventricular; VT, ventricular tachycardia. Reprinted from Journal of the American College of Cardiology, Vol. 61, Chandra N, Bastiaenen R, Papadakis M, Sharma S, Sudden cardiac death in young athletes: practical challenges and diagnostic dilemmas, Pages 1027–40, Copyright © 2013 American College of Cardiology Foundation, with permission from Elsevier.

Section 28 Sport and exercise medicine 6570 prior to rechecking and participation if suitable. In general, ath- letes learn their insulin requirements through evaluation of their responses to training and competition. Diabetic athletes typically will have blood glucose levels of 120 to 180 mg/dl (6.7–10 mmol/ litre) during exercise and they will perform best at levels of 70 to 150 mg/dl (3.9–8.3 mmol/litre). People with type 1 diabetes in endurance sports are at greatest risk of complications. Insulin should not be injected into areas around exercising muscles. Performing anaerobic spurts or resistance work before or after an endurance event, or both, can reduce hypogly- caemic episodes. It is also important to recognize that athletes are also at increased risk of delayed hypoglycaemia, typically 6 to 12 h (but up to 28 h) after exercise, due to inadequate caloric replacement soon after training. Mental health in sport Anxiety, sleep disruption, overtraining syndromes, and eating dis- orders are the most common psychological conditions in athletes, but overall there is no evidence of an increased incidence of psy- chological problems in athletes. Treatment is no different than in the general population. Moderate amounts of exercise act as an ef- fective antidepressant in mild to moderate depression. Illnesses that may be caused by sport Overtraining syndromes Physical training in sport involves overload, recovery, and adap- tation, leading to enhanced physical capacity. Overreaching (functional decrement lasting <2 weeks) or overtraining (lasting longer term) occurs when overload is excessive or recovery is limited, or both of these. Such overtraining syndromes are also collectively termed ‘unexplained underperformance syndrome’ (UUPS). UUPS often follows a heavy training block, with other triggers being poor recovery strategies (sleep, nutrition, and hydration), illnesses, and psychosocial factors. The athlete describes fatigue, often with myalgia, loss of appetite, sleep disruption, anxiety/de- pression, loss of libido, and frequent minor infections. A careful medical, nutritional, and training history should be taken and other causes of fatigue and other presenting symptoms should be excluded. UUPS is a diagnosis of exclusion and most fatigued athletes have an underlying cause (e.g. Epstein–Barr virus or iron deficiency). The mechanisms underlying UUPS are not fully established but have been proposed to include glycogen or glutamine depletion, or both; increased tryptophan uptake in the brain; excessive oxi- dative stress; and neuroendocrine and autonomic dysfunction (Table 28.1.4). Detecting and managing UUPS The detection of overtraining is through monitoring training load and adaptation throughout the season (Table 28.1.5). Since there are no reliable serological tools, athletes are monitored by self-reporting of symptoms and by performance-related measures. UUPS can be prevented by responding to early decrements in the monitoring parameters, ensuring good nutrition and hydration, allowing periods of recovery, and managing other stressors. Treatment commences with a period of rest, the extent of which is determined by the athlete’s physical and psychological status. Those with symptoms suggestive of anxiety/depression may benefit from a Table 28.1.4 Proposed mechanisms in UUPS Mechanism Consequences Glycogen depletion Peripheral fatigue, low mood Glutamine depletion Infections Excessive oxidative stress Muscle fatigue, soreness Cytokine release Inflammation and many of the typical symptoms of overtraining syndrome Excessive tryptophan uptake
by brain ‘Central fatigue’, mood symptoms Autonomic dysfunction Fatigue, reduced heart rate

variability, postural hypotension Hypothalamic dysfunction Dysregulation of neuroendocrine axis, many of the symptoms of overtraining syndrome Table 28.1.5 Monitoring training adaptation Measure Indices Self-report questionnaires Fatigue, mood, well-being, sleep, readiness to train Basic daily measures Resting heart rate, sleep patterns Performance Perceived exertion during training, heart rate response, sport-specific performance measures Physiological responses to submaximal and maximal exercise testing Heart rate, power output, blood lactate, blood cortisol, ACTH Table 28.1.3 European Society of Cardiology classification of 12- lead ECG abnormalities in the athlete Common and training-related
ECG changes Uncommon and training- unrelated ECG changes Sinus bradycardia T-wave inversion First-degree atrioventricular block ST-segment depression Incomplete right bundle branch block Pathological Q waves Early repolarization Left atrial enlargement Isolated QRS voltage criteria for left ventricular hypertrophy Right atrial enlargement Left axis deviation Right axis deviation Right ventricular hypertrophy Ventricular pre-excitation Right bundle branch block Left bundle branch block Long QT interval Short QT interval Brugada-like early repolarization

28.1 Sport and exercise medicine 6571 selective serotonin reuptake inhibitor, but these can reduce physical performance and increase the risk of heat illness. Training is com- menced in limited (e.g. 5–10-min) bouts and then progressed ac- cording to the athlete’s response when the athlete is asymptomatic and psychologically ready. Infections During times of intensive training or at a competition, minor illnesses are common but athletes are not typically immune defi- cient. Acute bouts of intensive exercise suppress some parameters of immune function for 3 to 24 h (Table 28.1.6). The effects are greatest when exercise is prolonged (>1.5 h), is of moderate or high intensity, and is performed without food intake. The changes are considered to be secondary to stress hormones, oxidative stress, and alterations in pro/anti-inflammatory cytokines. Heat, hu- midity, and cold do not seem to have an effect, but jet lag, insomnia, and individual predisposition seem to contribute. Although symptoms suggestive of upper respiratory tract infec- tion are more common during intense endurance training, such symptoms are likely to be related at least in part to inflammatory stimuli during exercise and the incidence of upper respiratory tract infection is overreported. Wherever possible, any athlete with a potentially contagious illness must be isolated until the chances of transmission have passed. Afebrile athletes with minor illnesses may continue to train at a reduced intensity and volume; those with fever, lower respira- tory tract symptoms, significant systemic upset, or a combination of these should rest. Anaemia in sport Sports anaemia is a term that should be reserved for a pseudo- anaemia that can occur when plasma volume expands with chronic training, resulting in haemodilution. Exercise-induced iron loss, and in some cases true anaemia, can occur due to a number of causes (Table 28.1.7), although iron deficiency is much less common in athletes than often suggested. Low serum ferritin levels are often reported, but ferritin is not a good measure of iron stores in athletes; the serum transferrin receptor concentration or serum transferrin receptor/ferritin ratio are better measures. Iron supplementation does not improve performance in athletes with normal iron stores and should be reserved for those who are truly iron deficient. Foot strike haem- olysis is usually clinically negligible: it can result in a reduction in haptoglobins but does not typically cause significant changes in haemoglobin, haematocrit, red blood cell count, or potassium concentration. Exertional heat illnesses Exertional heat illnesses include syncope, cramps, exhaustion, and heat stroke (Table 28.1.8) and are entirely preventable through acclimatization, hydration, cooling and clothing strategies, and avoidance of training and competition in extreme temperat- ures and humidity. It can occur in a variety of different climates in predisposed individuals (Table 28.1.9) and—unlike

classic heat stroke—hyperthermia is due to intrinsic heat production, but there is overlap between the two and both involve disordered thermoregulation. A wet-bulb globe temperature of 23 to 28°C is considered high risk for heat illnesses and competitions should not be held when this exceeds 28°C Heat stroke may be complicated by hypotension, arrhythmias, rhabdomyolysis, seizures, multiorgan damage, and ultimately death. Management of all heat illnesses should focus on prevention, early detection, and removal from training/competition. In heat ex- haustion/heat stroke, the core body temperature should be lowered to 37.5 to 38°C as quickly as is safely possible. Airway, breathing, and circulation must be assessed, with an appropriate immediate response to any significant perturbations, and neurological status must be monitored. The patient should be moved to a cooler en- vironment and ice packs applied to the neck, groins, and axillae. Spraying the body with tepid water is safe and effective in many cases: cold water immersion is more aggressive and should not be performed unless resuscitation facilities are available.
Table 28.1.6 Effects of intensive training on the immune system Parameter Examples Innate immunity Neutrophil function NK cell cytotoxicity Acquired immunity T-cell proliferation, cytokine production B-cell function, immunoglobulin production (including salivary IgA Antigen presentation by monocytes/macrophages Table 28.1.7 Causes of iron loss/anaemia in sport Cause Condition Gastrointestinal bleeding Gastrointestinal ischaemia/stress (long-distance running) nonsteroidal anti-inflammatory drug intake Haematuria Traumatic (contact sports) Bladder movement and microtrauma (long-distance running) Nontraumatic (cause uncertain:?nutcracker syndrome,?renal ischaemia,?lactic acidosis) Haemolysis Foot-strike trauma (long-distance running) Vascular compression by contracting muscles Nutritional deficiencies Any other medical cause of anaemia
Table 28.1.8 Description of heat illnesses Illness Rectal temperature Symptoms Signs Heat syncope Normal Dizziness, weakness Fainting Heat cramps Normal or <40°C Muscle cramps Muscles tight Heat exhaustion 37–40°C Dizziness, fatigue, headache, nausea, vomiting Flushed, sweating, cold clammy skin, normal CNS Heat stroke

> 40°C As heat exhaustion + CNS disturbance Hot skin, ± sweating, CNS disturbance CNS, central nervous system.

Section 28 Sport and exercise medicine 6572 Drugs in sport and doping Doping, which is the use of drugs to enhance performance, dates back to Greco-Roman times. In the modern era, it can be defined as the occurrence of one or more of the antidoping rule viola- tions, as described by the WADA. Violations include a prohibited substance's use, possession, trafficking, or presence in a test sample (Table 28.1.10); use of a prohibited method; association with those involved in doping; and not complying with testing rules. The WADA list is not exhaustive: similarly acting agents not described will also be considered as doping. Doping can be intentional or unintentional but is doping never- theless. It threatens the health of the athlete and the integrity of sport. Doping in 'elite' athletes can also negatively influence the behaviour of recreational athletes. Of all doping agents, anabolic steroids and growth hormone are the most significant threats to the health of recreational sportspeople: these are easily available, abuse is common, and their health consequences may lead to presenta- tion in a variety of clinical settings. Direct testing of high-performance athletes by urinalysis to assess for banned substances is used in most sports. Some sports such as cycling and athletics use the Athlete Biological Passport to detect changes in reticulocyte count and haemoglobin concentration as an indirect indication of doping. All high-

performance athletes and associated staff are educated about the WADA code, the dangers of doping, and testing proto- cols. It is the athlete who has the primary responsibility of adhering to the code. All physicians involved must also be familiar with the regulations, must adhere strictly to the code, and must obtain Therapeutic Use Exemptions from the national antidoping body for some medications, depending upon the WADA code at that time. Online referencing tools are available to check whether a medica- tion is permitted in training and competition for specific sports (e.g. http://www.globaldro.com). Exercise as medicine The wide benefits of structured physical activity (exercise) on health and disease are well established, but a significant proportion of the population do not meet recommended daily requirements (Figs. 28.1.4 and 28.1.5). Exercise behaviours and perceived barriers to exercise should be assessed when taking a general medical his- tory, and an exercise prescription considered as part of a medical management plan. The components and recommended amounts of a regular exercise programme are described in Table 28.1.11. Those individuals who cannot meet these recommendations may still benefit from lesser amounts. Moderate intensity exercise is defined as a rated perceived exertion of 12 to 13 on a scale of 6 to 20. There are some contraindications to exercise, as listed in Table 28.1.12. In the community, screening questionnaires such as the Par-Q can be used to detect those who are at risk. Recommendations for exercise in pregnancy are shown in Box 28.1.1. Table 28.1.9 Risk factors for heat illnesses Extrinsic Intrinsic High exertion Previous history Excessive clothing Childhood and older age Poor hydration Dehydration Lack of cooling strategies Alcohol High ambient temperature Sunburn or skin diseases High humidity Cardiovascular, metabolic or endocrine disease High wet-bulb
globe temperature Obesity Poor acclimatization Medications (antipsychotics, tricyclics, benzodiazepines, α-agonists, anticholinergics, monoamine oxidase inhibitors, antihypertensives, antihistamines, diet pills, recreational drugs (e.g. cocaine), laxatives, thyroxine Other medications Excessive motivation Sickle cell disease Table 28.1.10 The WADA prohibited list

1. Unapproved substances Any pharmacological substance not approved for human use
2. Substances prohibited in and out of competition Androgenic anabolic steroids and anabolic agents Peptide hormones, growth factors, related substances, and mimetics β2-agonists (limited amounts of inhaled salbutamol, formoterol, salmeterol permitted) Hormone and metabolic modulators Diuretics and masking agents
3. Prohibited methods in and out of competition Manipulation of blood and blood components Chemical and physical manipulation Gene doping
4. Prohibited substances during competition only Narcotics Cannabinoids Glucocorticoids
5. Prohibited substances in some sports β-blockers Alcohol 0 10 20 30 40 50 60 70 80 90 All Adults 16–24 25–34 35–44 45–54 55–64 65–74 75+ Percentage Age group Male Female Fig. 28.1.4 Percentage of adults meeting recommended physical activity levels in England (2012).

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150 min/week Or 20 min at vigorous intensity, 3 days per week, total
75 min/week Or A combination to total 500–1000 MET-min/week Resistance 2–3 days/week All major muscle groups One to four sets of 8–12 repetitions (moderate to high intensity) Neuromotor 2–3 days/week Proprioceptive exercises Flexibility At least 2 days per week, all major muscle groups Recommendations for children Age 5–18 Moderate to vigorous intensity physical activity for at least 60 min and up to several hours every day Vigorous-intensity activities, including those that strengthen muscle and bones, at least 3 days a week Age <5 Children of preschool age who are capable of walking unaided should be physically active daily for at least 180 min (3 h), spread throughout the day Table 28.1.12 Medical contraindications to exercise Absolute Relative Recent cardiac ischaemia Unstable angina Uncontrolled arrhythmias causing symptoms or haemodynamic consequences Symptomatic severe aortic stenosis Uncontrolled heart failure Acute pulmonary embolus Myocarditis, pericarditis Dissecting aneurysm Acute systemic infection Left main coronary artery stenosis Moderate coronary stenotic heart disease Significant electrolyte abnormalities Severe hypertension Tachy/bradyarrhythmia Hypertrophic cardiomyopathy or other type of outflow tract obstruction High-degree atrioventricular block Ventricular aneurysm Uncontrolled metabolic disease Chronic infectious disease (some types) Acute musculoskeletal conditions Box 28.1.1 Recommendations for exercise in pregnancy In the absence of medical or obstetric contraindications: • Perform 30 min or more of moderate exercise per day on most or all days of the week. • Avoid exercise in the supine position after the first trimester. • Stop exercise if fatigued and do not exercise to exhaustion. • Non-weight-bearing exercise is likely to help to reduce the risk of musculoskeletal injury. • Avoid any exercise where there is a risk of trauma. • Ensure there is an adequate diet to compensate for additional energy exposure. • Augment heat dissipation by wearing appropriate clothing, ensuring adequate hydration, and altering the environment as necessary. • Many of the physiological changes persist for 4 to 6 weeks postpartum and a return to a prepregnancy, higher-intensity exercise regimen should be gradual.

SECTION 29 Biochemistry in medicine Section editor: Christopher P. Conlon 29.1 The use of biochemical analysis for diagnosis and management 6577 Brian Shine and Nishan Guha