Paralympic medicine describes the health-care issues of those 4500 or so athletes who gather every 4 years to compete in 20 sports at the Summer Paralympic Games and in five sports at the Winter Paralympic Games. Paralympic athletes compete within six impairment groups: amputation or limb deficiencies, cerebral palsy, spinal cord-related disability, visual impairment, intellectual impairment, or a range of physically impairing disorders that do not fall into the other classification categories, known as les autres. The variety of impairments, many of which are severe, fluctuating, or progressive disorders (and are sometimes rare), makes maintenance of health in thousands of Paralympians while they undertake elite competition an unusual demand on health-care resources. The increased physical fitness of athletes with disabilities has important implications for cardiovascular risk reduction in a population for whom the prevalence of risk factors can be high.

Introduction
Paralympic medicine is the term used to describe health-care issues related to the Paralympic athlete. The word Paralympic evolved in the 1980s to describe elite sport for people with disabilities and derives from the Greek preposition para (meaning beside or alongside) and the word Olympics. Formal competitions for people with impairments began with the Stoke Mandeville Games in 1948, founded by Sir Ludwig Guttmann, a neurosurgeon at the spinal injuries unit at Stoke Mandeville Hospital (Aylesbury, UK). Every 4 years, following on from the Olympic Games, about 4000 athletes with different types of impairment assemble from 160 countries to compete in 20 summer sports. About 500 other athletes gather every 4 years to compete in five disciplines at the Winter Paralympic Games (table 1). The achievements of these athletes continue to inspire others. From a health-care perspective the Paralympic Games pose many challenges not faced in the Olympic Games. In this Series, we aim to address the issues that arise for health-care professionals while maintaining health in athletes with various impairments who are undertaking elite competition.

Paralympic sports
Summer and winter Paralympic sports are represented through international federations that ensure organised participation by athletes from many nations (table 2). Paralympic sports developed either as adaptations of an equivalent able-bodied sport or as one with no able-bodied equivalent devised to accommodate the impairment type—for example, goalball for athletes with visual impairment or boccia for athletes with severe hypertonia, ataxia, or athetosis. New sports are being added: adaptive rowing was included for the first time in Beijing in 2008, and Rio de Janeiro will host para-canoe and para-triathlon events in 2016. Nevertheless, Paralympic sport is a young discipline and creates new challenges from a medical perspective in understanding the patterns of injury.

Impairment groups
Historically, Paralympic sports tended to develop around a particular type of impairment, but as the sports increased in popularity a wider range of individuals with different physical impairments wanted to participate.

Key messages
- The term Paralympic—from the Greek preposition para (beside or alongside) and the word Olympics—describes elite sport for people with disabilities
- About 4000 Paralympic athletes compete in 20 summer sports and about 500 Paralympic athletes compete in five winter sports every 4 years
- Six impairment types exist: spinal cord-related disability, cerebral palsy, amputee, les autres, visual impairment, and intellectual impairment
- The complex mix of medical issues can be challenging for health-care providers and medical staff at the events, and medical needs of the athlete group need to be understood and medical staff trained appropriately
- Musculoskeletal injury patterns relate to the impairment type, the specific mechanics of the sport, and the equipment involved, but there is an absence of good quality research in this area for summer Paralympic sports
- Doping is not a key issue in Paralympic sport, but the nature of the athletes’ medical disorders means that they might need to take prohibited substances (but can apply for a therapeutic use exemption)
- Technology has a key role in improving sport performance, especially for athletes with leg prostheses or sport-specific wheelchairs; however, the long-term potential for injury associated with technological advancement is not understood
This rise in participation led to the definition of six main impairment types in Paralympic sports, including amputation or limb deficiency, cerebral palsy, spinal cord-related disability, visual impairment, and intellectual impairment. The sixth group, known as les autres, accommodates those athletes with physical impairments who are not covered by the other groups.

In 2007, the Paralympic Movement approved the International Paralympic Committee (IPC) Classification Code as an overarching structure for classification of Paralympic sports, and adopted the International Classification of Functioning, Disability, and Health (ICF) terminology and taxonomy to categorise impairment groups. To be eligible for Paralympic sports an athlete must have a primary permanent impairment, diagnosed objectively, in one of the ten following types: hypertonia, ataxia, athetosis, loss of muscle strength, loss of range of movement, loss of limb, limb deficiency, short stature, low vision, or intellectual impairment.

Some sports are designed exclusively for athletes with a certain impairment type (eg, judo for athletes with visual impairment) whereas others allow athletes with different impairment types to compete against each other (eg, swimming). To secure fair competition, athletes are grouped according to classifications. In Olympic sports, athletes are classified by sex, age, and weight, but in Paralympic sport minimum disability criteria for participation also exist, as does stratification of the athletes by severity of the impairment. The number of classifications and inclusion criteria differ by sport.

### Paralympic medical issues

#### Overview

By definition, the Paralympic athlete has a pre-existing medical disorder, including degenerative disorders, that makes activities of daily life challenging and risk of illness a common feature. The presence of some medical conditions might also raise the question for some healthcare professionals and carers as to whether people with some impairments should be participating in some sporting activities because of the inherent risk (eg, downhill ski-racing for a paraplegic sit-skier, or blind football for athletes with glaucoma). Notwithstanding the issue of autonomy of the individual, many physical, psychological, and social benefits arise from sporting participation that translate into reduced health-care costs. In one study, the mean number of hospital admissions per year after discharge was almost three times greater for non-athletes than it was for athletes. Furthermore, training intensity has increased substantially during the past 30 years, as noted by changes in physiological fitness in testing of elite athletes. Improved physical fitness reduces cardiovascular risk in Paralympic athletes, which is notable because a 51% prevalence of cardiovascular risk factors was reported in a study of Brazilian Paralympic athletes.

Increased physical fitness might also reduce the risk of injury. The Paralympic population of athletes is an atypical gathering of a wide variety of medical disorders, but some common medical issues will prevail in relation to the impairment types that need to be considered as part of medical provision at the event. For example, opening ceremonies with flashing lights and fireworks might induce seizures in Paralympic athletes, who have higher prevalence of epilepsy. Understanding the main medical issues relating to the impairment groups is key.
Spinal cord-related injury

Although the physical restrictions of loss of movement will be apparent, effects on the sensory and autonomic systems, which are not immediately obvious, challenge health and wellbeing of athletes with spinal cord-related injuries the most.

The neuropathic bladder predisposes to infections, urinary stones, and urinary-tract obstruction. Bladder control can be managed by catheterisation, or by use of a condom catheter and leg bag system. Infections are frequent and might be exacerbated by dehydration from training or travel. Such infections can cause pain, pyrexia, increased muscle spasticity, and autonomic dysreflexia. An effective and regular bowel programme is an important determinant of quality of life in individuals with spinal cord-related disability to enhance mood, self-esteem and body image, vocational aspirations, and relationships. Fear of bowel accidents prevents some individuals with spinal cord injuries from participating in sports, social activities, recreation, or employment. The exertion of sport might exacerbate this concern. Some athletes are particularly worried about increasing water intake because this increase means additional toilet breaks which can be a significant issue (eg, in Alpine skiing events). Difficulty with bowel evacuation might have a negative effect on an athlete’s preparation for competition.

Athletes with high spinal cord lesions (T6 and above) have restricted potential for improvements in cardiac output and maximum oxygen uptake. A loss of sympathetic cardiac innervation results in a maximum heart rate of 110–130 beats per min, which is determined by intrinsic sinoatrial activity. The restricted heart rate reserve and reduced stroke volume are compounded by a loss of catecholamine response to exercise and by the absence of the muscular venous pump in the legs. These factors limit aerobic performance and might not be understood by coaches and trainers from an able-bodied sport background who use heart rate as a proxy for training intensity.

Regulation of body temperature in athletes with high spinal cord lesions is impaired because of the loss of normal blood-flow regulation via the CNS and by the inability to sweat or shiver below the neurological level. However, athletes can use cooling and precooling strategies to combat the risk of hyperthermia. Loss of skin temperature sensation, in addition to the loss of autonomic control, will impair ability to detect thermal injury and puts the athlete at risk of hyperthermia or hypothermia.

Autonomic dysreflexia is unique to individuals with spinal cord-related lesions above T6. A painful stimulus below the level of the spinal lesion results in sympathetic discharge and cardiovascular responses that can enhance physical performance but also pose a risk to health. The stimulus triggers a series of reflexes resulting in abnormally high blood pressure, sweating, goose bumps, or flushing of the face and neck. The most common symptom is headache. Paralympic athletes who know that they might develop autonomic dysreflexia, sometimes voluntarily induce it before or during the event to enhance their performance. This practice, referred to as boosting, improves middle-distance wheelchair racing performance by about 10% in elite athletes with quadriplegia. However, autonomic dysreflexia can become a medical emergency resulting in stroke. Previously regarded as an anti-doping rule violation, autonomic dysreflexia is a health risk and any athlete in a dysreflexic state before the competition is withdrawn from the event on health grounds.

The protection that pressure, temperature, and pain sensation provide is compromised in insensate skin. Friction related to repetitive movements of sports, or humid environments (rowing, sailing, or wheelchair-bound activities), can result in pressure sores, particularly in tissue over bony prominences, especially on the

### Table 2: Paralympic sports

<table>
<thead>
<tr>
<th>Summer Games</th>
<th>Impairment groups</th>
<th>Governing body</th>
<th>Participation dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archery</td>
<td>Amputees, LA, CP, SCRD</td>
<td>FITA</td>
<td>1960–present</td>
</tr>
<tr>
<td>Athletics</td>
<td>Amputees, LA, CP, II, VI, SCRD</td>
<td>IPC</td>
<td>1960–present</td>
</tr>
<tr>
<td>Boccia</td>
<td>CP</td>
<td>CP-ISRA</td>
<td>1984–present</td>
</tr>
<tr>
<td>Cycling</td>
<td>Amputees, LA, CP, VI, SCRD</td>
<td>UCI</td>
<td>1988–present</td>
</tr>
<tr>
<td>Equestrian</td>
<td>Amputees, LA, CP, VI, SCRD</td>
<td>FEI</td>
<td>1996–present</td>
</tr>
<tr>
<td>Football (5-a-side)</td>
<td>VI</td>
<td>IBSA</td>
<td>2004–present</td>
</tr>
<tr>
<td>Football (7-a-side)</td>
<td>CP</td>
<td>CP-ISRA</td>
<td>1984–present</td>
</tr>
<tr>
<td>Goalball</td>
<td>VI</td>
<td>IBSA</td>
<td>1980–present</td>
</tr>
<tr>
<td>Judo</td>
<td>VI</td>
<td>IBSA</td>
<td>1988–present</td>
</tr>
<tr>
<td>Powerlifting</td>
<td>Amputees, LA, CP, SCRD</td>
<td>IPC</td>
<td>1964–present</td>
</tr>
<tr>
<td>Rowing</td>
<td>Amputees, LA, CP, VI, SCRD</td>
<td>FISA</td>
<td>2008–present</td>
</tr>
<tr>
<td>Sailing</td>
<td>Amputees, LA, CP, VI, SCRD</td>
<td>IFDS</td>
<td>2000–present</td>
</tr>
<tr>
<td>Shooting</td>
<td>Amputees, LA, CP, VI, SCRD</td>
<td>IPC</td>
<td>1976–present</td>
</tr>
<tr>
<td>Swimming</td>
<td>Amputees, LA, CP, II, VI, SCRD</td>
<td>IPC</td>
<td>1960–present</td>
</tr>
<tr>
<td>Table tennis</td>
<td>Amputees, LA, CP, SCRD</td>
<td>ITTF</td>
<td>1960–present</td>
</tr>
<tr>
<td>Volleyball</td>
<td>Amputees, LA</td>
<td>WOVD</td>
<td>1976–present</td>
</tr>
<tr>
<td>Wheelchair basketball</td>
<td>SCRD, amputees, LA, II</td>
<td>IWBF</td>
<td>1960–present</td>
</tr>
<tr>
<td>Wheelchair fencing</td>
<td>SCRD</td>
<td>IWAS</td>
<td>1960–present</td>
</tr>
<tr>
<td>Wheelchair rugby</td>
<td>SCRD</td>
<td>IWRF</td>
<td>2000–present</td>
</tr>
<tr>
<td>Wheelchair tennis</td>
<td>SCRD</td>
<td>ITTF</td>
<td>1992–present</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Winter Games</th>
<th>Impairment groups</th>
<th>Governing body</th>
<th>Participation dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpine skiing</td>
<td>Amputees, LA, CP, VI, SCRD</td>
<td>IPC</td>
<td>1976–present</td>
</tr>
<tr>
<td>Biathlon</td>
<td>Amputees, LA, CP, VI, SCRD</td>
<td>IPC</td>
<td>1988–present</td>
</tr>
<tr>
<td>Ice sledge hockey</td>
<td>Amputees, LA, CP, SCRD</td>
<td>IPC</td>
<td>1984–present</td>
</tr>
<tr>
<td>Nordic skiing</td>
<td>Amputees, LA, CP, VI, SCRD</td>
<td>IPC</td>
<td>1976–present</td>
</tr>
<tr>
<td>Wheelchair curling</td>
<td>Amputees, LA, CP, SCRD</td>
<td>WCF</td>
<td>2006–present</td>
</tr>
</tbody>
</table>

buttocks and hips. These injuries might also occur from long-haul travel. Athletes vulnerable to pressure sores are advised to regularly inspect insensitive skin areas. Persistent redness, hardening of the skin, or a raised area are preliminary signs of pressure sores and should immediately be relieved of all pressure until healthy skin colour returns. If not treated appropriately, skin breakdown can progress to serious deep infection in muscle and bone. Another risk factor for skin breakdown is oedema from impaired venous return, attributable to the inability of muscular pumping in paralysed limbs, particularly when the blood flow is obstructed by clothing or straps used to secure the athlete in the wheelchair.

Cerebral palsy
Cerebral palsy and traumatic brain injury have features other than the movement-related disorders that restrict sport function and that will influence health care provision at an event. Disorders of speech, hearing, and vision can affect communication. Although communication difficulties should not necessarily be attributed to impaired cognitive functioning, this difficulty can also be a factor. Increased muscle tone necessitates stretching to maintain range of motion, but if done too close to activity can impair performance. Botulinum toxin can be used in the management of spasticity, but any medical treatment that improves function can also change the athlete’s classification.28,29 Athletes with cerebral palsy are also more likely to have convulsive disorders. Fatigue from intense training, becoming overly stressed, or dehydration, might induce seizures.20 Team doctors should monitor susceptible athletes closely in tapering off and cool-down periods, when seizures are most likely to occur. Athletes with high supportive needs are less able to take fluids during sports without assistance and might have thermoregulatory problems. Moreover, those athletes who have communication or cognitive disorders might not readily report symptoms of heat or cold intolerance.

Amputees
Different prostheses can be used for activities of daily living and sport, and a comfortable fit is necessary for both. Chafing or impact of the residual limb can result in localised or systemic infection. Athletes with leg prostheses might not be accustomed to walking the distances associated with competing at the Paralympic Games, which can cause increased loading and skin breakdown.9 In athletes who had an amputation for neoplastic disease, recurrences or metastatic disease can occur. The loss of a limb changes the ratio of surface area to body volume and thus athletes who have had more than one amputation might have difficulties with thermoregulation.20

Les autres
Athletes in les autres group are challenging from a medical perspective because of the diverse diagnoses identified, including rare syndromes with anomalies in different systems. Examples include spondyloepiphyseal dysplasia with neurologic or respiratory problems, or Becker muscular dystrophy with cardiomyopathy or arrhythmia.

Visually impaired athletes
Eligible visually impaired athletes have damage to one or more of the components of the visual system, which can include damage to eye structure or receptors, the optic nerve or optic pathway, or visual cortex. Depending on the sport, athletes wear blackout goggles (eg, blind football and goalball) or compete in categories depending on their residual function (eg, winter sports, athletics, swimming, and equestrian). Some clinical manifestations of vision impairment can cause sport-specific risks. For example, athletes with increased ocular pressure may participate in sports with risk of impact to the head (eg, heading in blind football or hitting the pool end in swimming). Athletes with a visual impairment might have some problems orienting themselves in the large new environment of the Paralympic village, and collision injuries or tripping can occur. This group also has practical difficulties in self-monitoring hydration through urine colour and volume. Sleep patterns occasionally are impaired in those without any perception of light11 and this factor might affect recovery from hard training.12

Intellectual impairment
Athletes with intellectual impairment who participate in Paralympic sport (athletics, swimming, and table tennis; table 2) have to meet classification criteria that are specific to their sports. A diagnosis of intellectual impairment compatible with the American Association on Intellectual and Developmental Disability definition of intellectual disability10 is a prerequisite. Additionally, classifications specific to the sports exist for conation; the mental processes that activate or direct behaviour and action, such as visuospatial intelligence. The origin of the intellectual impairment might be associated with physical limitations or psychiatric impairment. In addition to the general aspects of care of vulnerable adults, changes in environment and stress-evoking situations need to be considered when assisting these athletes. Athletes with intellectual impairment first competed in the Atlanta 1996 Paralympic Games, but controversy about the classification system in Sydney in 2000—specifically, athletes competing without a verified impairment—led to their exclusion in 2004 and 2008. A more rigorous system of classification, including the effect of the impairment on sport function, will allow athletes to compete in London 2012.

Injuries in Paralympic sports
A comprehensive review34 of the epidemiology of injury in Paralympic sports emphasised the deficiency that exists in availability of quality studies. Most studies used self-reporting of symptoms rather than medical diagnoses.
and tended to aggregate sports with the generic term wheelchair athletes.\textsuperscript{35,36,60} 16 (80%) of 20 summer Paralympic sports involve athletes who use wheelchairs some of the time. Some athletes use a wheelchair for sports but are fully ambulant with prostheses in activities of daily living. Other athletes might use powered wheelchairs for both daily activities and sport.

Just as in able-bodied athletes, Paralympians can have injuries related to the biomechanics of sport, the equipment used, and the interface between athlete and equipment. Wheelchair users are especially susceptible to injuries related to repetitive motions of the shoulder and elbow joints, and contact surfaces between the residual limb and socket. Although the shoulder has been identified as a potential source of overuse injury in the wheelchair athlete, some evidence suggests that sport has a protective effect compared with the sedentary wheelchair user.\textsuperscript{47}

Paralympic athletes often report scrapes, cuts, bruises, blisters, and floor and wheel burns. Such athletes are especially at risk of accidental injury from incidental contact with the wheelchair, prosthesis, or ground, after a fall. This risk is increased when the skin is wet. Athletes sensitive to abrasions and lacerations often wear protective clothing or gloves, or strap themselves into their chairs to reduce the rate of injuries during falls. The outcome of seemingly minor injuries can be substantial when the skin is insensitive or at the interface with a prosthesis.

Although fractures are not a common issue they do occur in some sports (eg, collision injuries in alpine skiing or ice sledge hockey), especially when there is the potential for high speeds and contact or collision. Because the bone density of paralysed athletes is reduced compared with non-paralysed individuals, bones can fracture from minor injuries, and this factor needs to be considered in assessment of what should be deemed as minimal trauma. Many athletes lack the sensation that accompanies a fracture, thus evidence of an abnormal body position, swelling, redness, bruising, or grinding sensations should lead to precautionary stabilisation and examination through appropriate radiological imaging. Fracture might also be a cause of autonomic dysreflexia. Fractures can be attributable to falls that result from reduced coordination (eg, athletes with cerebral palsy), loss of proprioception (eg, running on prostheses), or unforeseen obstacles (eg, visually impaired athletes). The effect of a limb fracture in an athlete who already has an amputation will be striking.

The understanding of injury in winter Paralympic sports is somewhat clearer than it is for summer sports after the institution of the IPC injury surveillance system at the Salt Lake City Winter Paralympic Games in 2002.\textsuperscript{41} Injuries have been monitored at three Winter Paralympic Games.\textsuperscript{19} In 2002, five foot and ankle fractures occurred in ice sledge hockey players, resulting in 33% of reported injuries in this sport. Following this study,\textsuperscript{61} a recommendation was made to change the rules on protective clothing and to equalise the height of the sledges to reduce crossover collisions. Since the rule changes in 2005, only one leg fracture occurred in two subsequent Winter Paralympic Games. An increased incidence of injury in all sports was noted in 2010 (120 [24%] of 505 athletes) compared with previous Winter Paralympic Games (39 [9%] of 416 athletes in 2002 and 40 [8%] of 474 athletes in 2006).\textsuperscript{38,39} but this increase probably was due to improved data capture of less severe injuries.\textsuperscript{39} However, longitudinal studies in individual sports are needed to fully understand the injury patterns and prevention implications.\textsuperscript{40}

### Equipment

An understanding of adaptive equipment is required for Paralympic medical care. Prostheses and wheelchairs are fundamental to allow some people with a disability to undertake the tasks of daily living, and to participate in sport. Advances in technology underpin such assistive devices.\textsuperscript{47} For example, the development of an energy-storing prosthetic foot can make a leg amputee’s gait more efficient and ambulation faster. The application of such technology in sport can be controversial, as in the case of Oscar Pistorius (sometimes known as the Blade-Runner), whose prosthetic feet are purported to give him an advantage over able-bodied runners.\textsuperscript{42,43} As Paralympic sport evolves, athletes have noted that standard devices restrict their performance, and technological developments have been introduced, including improvements in wheelchair design and prostheses, seated throwing chairs, and adaptive sit skis. Amputee runners have benefited strikingly from advances in prosthetic technology, but no consideration has yet been given to the influence on the stump-socket interface on the prosthesis and the body. This issue is especially important because of the increased loads on the body in high-intensity sport. Amputation in the lower leg changes the orientation of the pelvis and vertebral column,\textsuperscript{44} which might have substantial effects and necessitates assessment of new technologies in a holistic manner. Much the same need applies for use of new wheelchairs or sit-skis. The increase in the mechanical ability of any sports assistive device should be considered in the context of the athlete, and the challenge to effectively match technology with the athletes’ requirements.\textsuperscript{45}

### Coordination of event medical services

The IPC has recognised the need to have an overarching athlete health and safety policy, and developed the IPC Medical Code.\textsuperscript{47} Despite the best planning, accidents occur. Organisers need to recruit experienced medical personnel, and carefully establish contingency plans.\textsuperscript{46} Before an event, medical staff need to have information about common disability-related issues, medical services, facilities, policies, and procedures.\textsuperscript{39} Prosthetists, orthotists, and wheelchair repair specialists should be available. Emergency medical teams should have experience in extricating athletes from adaptive equipment (ie, monoski shells, ice sledges, racing chairs, hand
cycles), or at least familiarise themselves with the adaptive equipment that is in use.

Anti-doping

The principle of strict liability applies equally in Paralympic sport and Olympic Sport. Although doping is not thought to be a substantial issue in Paralympic sport, competitors in the powerlifting events have a history of use of prohibited substances, particularly anabolic drugs. Sample collection is different for Paralympic athletes from Olympic athletes. The use of catheters for collection of the sample is permitted, but urine cannot be collected from a leg bag without previous emptying in the doping control station. Athletes with a visual or intellectual impairment need supervision by an accompanying individual to ensure integrity of the sample.

Conclusions

Provision of health care for Paralympic athletes is probably the most challenging and rewarding area of sports medicine. Such provision produces many issues for doctors caring for more than 4000 athletes with various medical disorders, who are undertaking sports at an elite level. The IPC will undertake an injury and illness surveillance programme at the 2012 Summer Paralympic Games for the first time, which will enhance understanding of medical issues. Sports medicine needs to undertake sport-specific longitudinal studies to understand injury risk and to develop prevention strategies.

An increasing number of opportunities exist for education in Paralympic medicine, including masters programmes, international sports medicine conference programmes (eg, the American college of Sports Medicine annual conference, the IOC conference on sports injury prevention), and International Federation of Sports Medicine team doctor courses.

Individuals with impairments are able to achieve extraordinary levels of performance, indicative of the Paralympic values of the IPC—courage, determination, inspiration, and equality. Paralympic Sport is an agent for change to break down social barriers of discrimination for individuals with a disability, and the 2012 Summer Paralympic Games in London will enable more people than ever to witness the inspiring achievements of these athletes.

Contributors

Both authors contributed to the writing of the Series, with the lead taken by NW.

Conflicts of interest

We declare that we have no conflicts of interest.

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