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Review

Exercise and sports science Australia (ESSA) position statement on exercise and spinal cord injury

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ABSTRACT

Traumatic spinal cord injury (SCI) may result in tetraplegia (motor and/or sensory nervous system impairment of the arms, trunk and legs) or paraplegia (motor and/or sensory impairment of the trunk and/or legs only). The adverse effects of SCI on health, fitness and functioning are frequently compounded by profoundly sedentary behaviour. People with paraplegia (PP) and tetraplegia (TP) have reduced exercise capacity due to paralysis/paresis and reduced exercising stroke volume. TP often further reduces exercise capacity due to lower maximum heart-rate and respiratory function. There is strong, consistent evidence that exercise can improve cardiorespiratory fitness and muscular strength in people with SCI. There is emerging evidence for a range of other exercise benefits, including reduced risk of cardiometabolic disease, depression and shoulder pain, as well as improved respiratory function, quality-of-life and functional independence. Exercise recommendations for people with SCI are: ≥30 min of moderate aerobic exercise on ≥5 d/week or ≥20 min of vigorous aerobic ≥3 d/week; strength training on ≥2 d/week, including scapula stabilisers and posterior shoulder girdle; and ≥2 d/week flexibility training, including shoulder internal and external rotators. These recommendations may be aspirational for profoundly inactive clients and stratification into "beginning", "intermediate" and "advanced" will assist application of the recommendations in clinical practice. Flexibility exercise is recommended to preserve upper limb function but may not prevent contracture. For people with TP, Rating of Perceived Exertion may provide a more valid indication of exercise intensity than heart rate. The safety and effectiveness of exercise interventions can be enhanced by initial screening for autonomic dysreflexia, orthostatic hypotension, exercise-induced hypotension, thermoregulatory dysfunction, pressure sores, spasticity and pain.

1. Background

Spinal cord injury (SCI) refers to damage to neural elements of the spinal canal (spinal cord, cauda equina and spinal nerves), frequently resulting in permanent impairments of motor, sensory and/or autonomic function.[1,2] Aetiology may be traumatic (e.g., motor vehicle accident and falls) or non-traumatic (e.g., myelomengiocele, spinal stenosis, transverse myelitis and tumour).[2]

Spinal cord injury profoundly affects functioning at the level of body systems (e.g., neuromusculoskeletal and cardiovascular functioning), person (e.g., walking, grasping, lifting and carrying) and society (e.g., employment, sports participation, social engagement).[3] It is extremely costly in human, social and economic terms.[3] The global incident rate of SCI is estimated at 23 cases per million (179,312 cases per annum), although there is considerable regional variation, from North America (40 per million) to Australia (15 per million).[3] Globally, the incidence of SCI is highest among males aged 18–32 years and, in developed countries with ageing populations, people over 65 years.[3] Worldwide, more than 2 million people live with an SCI.[3] Given the high cost, geographic spread and relatively high incidence of SCI, evidence-based interventions which assist people with SCI to optimize their health fitness and functioning are critical.

Physical activity is defined as "any bodily movement produced by skeletal muscle that results in caloric expenditure".[4] Exercise is a specific type of physical activity that is planned, structured

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and repetitive and done to improve or maintain fitness.[4] Evidence indicates that people with SCI are profoundly inactive[5] and this inactivity is causally linked to an increased risk of preventable diseases that compound the primary effects of SCI.[6,7] Exercise interventions are an effective means of increasing physical activity and reducing preventable disease risk in people with SCI.[7] Additionally, specific types of exercise have been shown to enhance health, fitness and functioning in people with SCI. The aim of this Position Statement is to provide practitioners with evidence-based recommendations for prescription of safe, effective exercise interventions for adults with chronic SCI (≥six months post-injury). The Statement focuses on exercise for people who use hand-rim propelled wheelchairs because evidence indicates that a substantial proportion of people with SCI use such chairs some or all of the time [8], [9] however much of the information provided is relevant to people with SCI who have more severe activity limitations (e.g., people who use power wheelchairs) as well as less severe (e.g., people with SCI who walk). The Statement focuses on exercise using voluntarily activated muscles rather than assistive technology such as, Functional Electrical Stimulation and Body Weight Supported Treadmill Training. Practitioners interested in these two modalities are directed to recent reviews cited in the reference list.[10,11]

2. Motor, sensory and autonomic effects of SCI

The extent of motor, sensory and autonomic dysfunction resulting from SCI depend upon the segmental level of the injury and the completeness of the injury.[12] Tetraplegia (preferred to quadriplegia) refers to injury to any of the spinal segments from C1 to C8 and results in impairments of arm, trunk and leg function.[1] Paraplegia (PP) refers to injury in the thoracic, lumbar or sacral segments and arm function is spared. Approximately 53% of SCI results in tetraplegia (TP) and 47% in PP.[12]

Motor and sensory completeness of an SCI is classified according to the American Spinal Injury Association (ASIA) Impairment Scale (AIS).[1] There are five AIS classifications, from AIS A (complete, no motor or sensory function in sacral segments S4–S5) to AIS E (a person with initial deficits who has normal motor and sensory function at the time of assessment).[1] The AIS scale does not include assessment of autonomic completeness, which must be assessed separately.[13] As acute management of SCI improves, the proportion of incomplete SCI is increasing.[14] Approximately 65% of SCI are incomplete, with incomplete TP (38%) being more common than incomplete PP (27%).[12]

Table 1 presents the motor, sensory and autonomic function typical of a person with an AIS A injury that is motor, sensory and autonomically complete. The third column presents the typical profile of a person whose lowest intact segmental level is C1, C2 or C3, and each subsequent column presents the profile of a progressively lower segment or group of segments. Table 1 illustrates that complete injuries can result in an extremely wide range of functional profiles—from ventilator-dependent power wheelchair users with significant cardiorespiratory compromise, to independent walkers with no cardiovascular impairments. Table 1 also indicates that when injuries are motor, sensory and autonomically complete, functioning is generally predictable, increasing with lower segmental level of injury. However, when injuries are incomplete (e.g., AIS classification B, C or D), functioning cannot be predicted, even when segmental level is identical—a sample of people with a C4 SCI that is classified AIS C may include people who require a power wheelchair for mobility through to people who are able to walk independently. In addition to the effects of lesion level and lesion completeness, the functioning of a person with SCI is also affected by age, physical activity level and comorbidities such as spasticity, contractures and pain.

3. Exercise capacity in SCI

Many people with SCI are unable to engage in lower-limb exercise and must use upper-limb modes such as wheelchair pushing or upper-limb ergometers (e.g., arm-crank or wheelchair). This constraint is important because, compared to lower limb exercise, upper limb exercise elicits a considerably reduced cardiovascular response.[15] For example, when people without SCI perform arm cycling, maximal power output (PO_{max}) and VO_{2peak} are reduced by approximately 40% and 25%, respectively compared with leg cycling.[15] Efficiency is also reduced—O_2 uptake (and therefore physical strain) for any given power output is greater for arm cycling than for leg cranking.

When exercise capacity is assessed using arm-crank ergometry, there is no significant difference between VO_{2peak} for people with or without paraplegia (PP).[15] Parity is achieved at least partly because habitual wheelchair use leads to physiological adaptations in the upper-limb musculature of PP, reducing glycogenolysis and increasing the rate of lipid utilisation.[15] Even with the limitations inherent to upper-limb exercise, SCI athletes can achieve a high VO_{2peak} (e.g., a mean of 40 ml kg^{-1} min^{-1} for a Paralympic wheelchair basketball team[16]).

The above evidence notwithstanding, SCI adversely affects exercise capacity for a number of reasons. First, as lesion level increases, voluntarily activated muscle mass decreases (see Table 1), reducing oxidative capacity and therefore maximal oxygen uptake and maximum caloric expenditure from exercise. This effect is particularly pronounced in TP because the muscles required for arm exercise are partially paralysed in addition to paralysis of the trunk and legs.[15] Second, as lesion level increases, sympathetic vasoconstrictive capacity gradually diminishes, reducing venous return and, in accordance with the Frank–Starling mechanism, exercising stroke volume does not rise to the same extent as in the non-disabled. At submaximal exercise levels, cardiac output can be maintained by a compensatory increase in heart rate, but this is not possible during maximal exercise, reducing maximal exercise capacity.

For TP, two additional factors negatively impact on exercise capacity. The first is that, for those with absent or reduced cardiac sympathetic innervation, heart rate increases rely to a proportionally greater extent on parasympathetic withdrawal and circulating catecholamines,[15] and maximal heart rate may be as low as 130 bpm.[15] However, it should be noted that recent evidence suggests that even those with AIS A tetraplegia may retain autonomic function that is sufficient to achieve normal or near-normal responses during exercise.[13] The second negative impact is that, while respiratory function is normal or near normal in most people with PP (see Table 1), it is approximately 60% of normal values in TP.[15] The combination of reduced active muscle mass, impaired venous return, neurologically limited maximum heart rate and decreased respiratory function significantly reduces exercise capacity in TP compared with PP. Exercise capacity norms have been previously published: for TP, VO_{2peak} of <7.6 ml kg^{-1} min^{-1} is poor and >16.95 ml kg^{-1} min^{-1} is excellent;[17] for PP, VO_{2peak} of <16.5 ml kg^{-1} min^{-1} is poor and >34.4 ml kg^{-1} min^{-1} is excellent.

4. Benefits of exercise

There are 2 exercise benefits for which there is very strong and consistent evidence–improved cardiorespiratory fitness (CRF) and improved muscular strength.[6] Evidence indicates that CRF of both TP and PP improves in response to upper-limb aerobic training or circuit training.[16,18–20] Resistance training also improves CRF in PP.[20] In a review of 14 exercise training studies, VO_{2peak} improved by a mean of 17.6 ± 11.2% and PO by 26.1 ± 15.6%, with a trend for greater gains in PP than TP.[16]