consequences for rowing. If the athlete has short hamstrings, then to achieve the appropriate posture at the catch, he/she may overflex the spine. Hence it is important for rowers to include hamstring stretching exercises in their training programmes.

In summary, the large forces combined with the repetitive nature of the activity create the potential for injury to the lumbar spine structures during rowing. However, the warming up activities of rowers, the time at which they train during the day, the control of lumbar motion by specific muscle activation patterns, and the flexibility of the hamstring muscles can influence these forces. Incorporating these factors into training and rehabilitation programmes may lead to a reduction in the incidence of back injuries in rowers.

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Why exercise in paraplegia?

Spinal cord injury leads to two dramatic changes: not only is there loss of muscle function and a large amount of muscle, but also susceptibility to inactivity related diseases, such as obesity, insulin resistance, type II diabetes, and coronary heart disease, increases.[1] Previously, one of the major problems and causes of death for people with spinal cord injuries was infection, but recently, coronary heart disease has become more prominent. The possibilities for exercise in people with spinal cord injuries are limited to either performing voluntary exercise with non-paralysed muscle groups—for example, arm exercises, especially in the paraplegic—or subjecting themselves to electrically induced exercise through stimulation of motor nerves either with surface electrodes or after implantation of electrodes.

Whereas voluntary arm exercise can provide a certain stimulus to the cardiorespiratory system, it has recently been shown that stimulation of paralysed lower extremity muscles alone or in combination with arm cranking will not only increase energy combustion, but also activate more muscle groups and thus influence metabolic changes such as insulin resistance in a potentially better way. After the use of electrical stimulation for bladder and intestines, the possibility of stimulating paralysed muscle in a functional manner came to the fore at the beginning of the 1980s and allowed the development of a computerised bicycle (FES).[2] The use of such a bicycle for functional electrical stimulation has been shown not only to improve maximal oxygen uptake and endurance of the stimulated muscles, but also to cause muscle hypertrophy and muscle fibre shift from fast twitch type 2X to 2A.[3]

In addition to these effects, oxidative enzyme activity has also been shown to increase after several weeks of training.[4] This occurs at a faster rate than the shift in fibre type, indicating different time patterns for the adaptation of these two systems. In addition, the collagen in muscle adapts to electrical stimulation, and it has been shown that type 4 collagen, which is predominant in the basal membrane, increases its turnover without any net increase in total amount, indicating possible reorganisation of this connective tissue.[5] In addition to these effects, expression of the protein used for glucose transport (Glut4) increases with training and so does insulin stimulated glucose uptake in the muscle.[6]

Finally, it has been shown that functional electrical stimulation of paralysed legs increases bone mineral content of the tibial region. In studies using FES bicycling, high frequencies were used for stimulation, and no type I fibres were observed after this training. However, stimulation with lower frequencies actually seems to produce an increase in mRNA for myosin heavy chain type I after several weeks of training.[7]

In combination, the effects of functional electrical stimulation counteract the enzyme activity associated changes in people with spinal cord injuries and should thereby have a preventive effect.

In addition to these effects, electrical stimulation of partially paralysed muscle groups such as wrist extensor and muscles in tetraplegic people has been shown to result in improved function and endurance of the affected arm allowing more daily functions to be performed than before the training programme.[8]

Finally, it seems that training in people with spinal cord injuries improves their general wellbeing, temperature regulation, and sleeping patterns and reduces pressure sores, all important effects in addition to those mentioned above. It is therefore vital to encourage physical activity, including the use of electrical stimulation devices, in this group of patients in order to prevent diseases associated with physical inactivity. Such diseases not only occur in this group of people, but also reflect the general pattern in our modern inactive society. Results obtained in research on people with spinal cord injuries may therefore help to provide a basis for recommendations on exercise in the general population also.

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Magnetic resonance technology in training and sports

When muscles are used to perform physical activity they must metabolise available fuel to generate energy for contraction. The harder a muscle must work, the more fuel is required. The relation between how hard muscles must work and their need for fuel is an area of intense interest in the study of human performance. In the past, intramuscular energy metabolism has been measured directly by muscle biopsies,[1] which are invasive. During the last two decades, the sophistication of magnetic resonance (MR) technology has steadily improved. Using magnetic resonance spectroscopy (MRS), it is now possible to detect non-invasively changes in a number of important intramuscular fuel sources, such as muscle glycogen,[2–5] during exercise and recovery. Magnetic resonance imaging (MRI) has been used for some time to examine anatomical effects of sport and training.[6] Recently it has become possible to measure exercise induced physiological changes with MRI and use information from these measurements to determine muscle activity patterns.[7–9] These more recent advances open up a new range of possibilities to use MR technology not only as a diagnostic tool, as in the past, but in a proactive manner to assess human performance.

Although MRS cannot completely replace the direct biochemical measurements obtained from muscle biopsy samples, it offers distinct advantages that are not available with biopsies. It provides a non-invasive direct measurement of muscle energy metabolite concentrations (glycogen, creatine phosphate, glucose 6-phosphate, inorganic phosphate, and lactate) with better time resolution, repeatability, and somewhat better precision.[2–5] The drawbacks of MRS (the availability of expensive equipment and an inability to distinguish between muscle fibre types) are offset by the muscle biopsy technique.[3] When MRS and muscle biopsy samples are obtained concurrently, the small amount of tissue obtained in the biopsy sample (50–80 mg muscle) does not need to be used to determine muscle glycogen concentration and can be used to assess other important metabolic indicators such as enzymatic activities. This complementary nature of MRS and muscle biopsy means that, when used in combination, they become a powerful tool for optimising athletic training programmes. In such a programme, MRS samples obtained from individual athletes may be used to (*a*) monitor the effectiveness of different carbohydrate loading protocols, (*b*) optimise the efficiency of training schedules and avoid overtraining, (*c*) assess metabolic recovery from training sessions, and (*d*) measure the athlete's state of readiness to participate in an event. Ultimately MRS and biopsy measurements are indicators of an athlete's physical condition at a specific point in time (pre-season, mid-season, end of the season), and therefore are of great benefit in optimising an athlete's performance and minimising the risk of injury.

MRI is another non-invasive method that has the potential to be a powerful training tool, and it is much more universally available than MRS. Muscles that have actively participated in the performance of an exercise appear hyperintense on MR images.[7] It is thought that this increase in MRI signal results from movement of fluid into the exercised muscle, brought about by increased metabolic activity in the muscle.[8 9] Electromyography (EMG) measures neural activation as differences in electrical activity across the muscle membrane and has been used traditionally to measure muscle activity. It has the advantage that it is sensitive to small changes in electrical activity and it can detect the onset of neural fatigue.[10] However, it cannot be used non-invasively to study deep muscles, and it can only study the muscles that it is set up to study.[10] MRI can be used to study both surface muscles and deep muscles non-invasively, and may be a better indicator of how hard a muscle has worked.[10] As with MRS and muscle biopsy, there is a great potential to use MRI and EMG in combination to optimise a training programme. Traditional MRI methods can be used to study an athlete's anatomy, making measurements such as heart chamber volumes (particularly left ventricle) and arterial development (measured as the arterial diameter of major arteries). Both of these variables are augmented by training and therefore are a measure of the degree of training of an athlete.[11] Functional MRI methods can be used to assess the muscle activation patterns that contribute to the complex biomechanical