

## WHEELCHAIR ATHLETES AND THEIR CONSIDERATIONS: A REVIEW

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### **Introduction**

To achieve success in life and in sports, athlete with disability must have a combination of hard work, methods of training, sacrifice and determination, incentive and opportunity. The situation of persons with spinal cord injuries or amputations, which usually leads to permanent inability or death until few decades ago changed completely after the Second World War. The increase in number of disabled person's situation stimulated the creation of the rehabilitation centers in the United States and England (Steward, Peterson 1997).

Who else if not Dr. Ludwig Guttmann, who pioneered in the treatment and recovery of persons with disabilities in England, at the Stoke Mandeville Rehabilitation Unit (Steward, Peterson 1997). The history of sports for the disabled began in England, at Aylesbury. Following a request from the British government, Dr. Ludwig Guttmann, who was a neurologist that had escaped from the Nazi persecution to Jews in Germany, created the national Centre to Spinal Cord Injury at the Stoke Mandeville Hospital to treat the injured British soldiers from Second World War. From here, United States and Germany, in 1948 this concept of introducing sports for injured people already achieved an official status with the first international competition the Stoke Mandeville games. With the growth of this kind of activity in daily life of persons with disabilities, it was perceived that disabled persons could obtain the same physical and emotional benefits than able-bodied persons, leading to an increased need to overcome limitations, opponents and records. Part of therapy techniques that been introduced for the treatment for persons with disabilities, and advanced technologies, involvement in sports activities is an important medium for the rehabilitation and reintegration of persons with disabilities to society. The introduction of sports therapy in rehabilitation, as well as further involvement in sports depends on the severity of the injury, might lead the person to become a non-competitive athlete, a paralympic sportsmen and sportswomen or even a paralympic champion (Kottke, Lehman 1994).

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### Spinal cord injury

Spinal cord injury results in reduced vasomotor and sweating responses below the level of lesion with subsequent thermoregulatory dysfunction (Guttmann, Silver & Wyndham 1958). Studies of paraplegic individuals at rest and during exercise have shown that thermoregulatory responses are proportional to the level of lesion, reflecting the amount of sympathetic nervous system available for sweating and blood distribution (Guttmann, Silver & Wyndham 1958; Petrofsky 1992; Price & Campbell 2003). However, when the level of spinal cord lesion is in the cervical region resulting in tetraplegia (or quadriplegia), much greater thermal strain is observed during both resting and exercise heat exposure (Guttmann, Silver & Wyndham 1958; Price & Campbell 2003). We can see for example during resting heat exposure, tetraplegic individuals compared with paraplegic individuals, who in turn demonstrate greater increases than able-bodied subjects (Guttmann, Silver & Wyndham 1958). When exercising in hot and humid condition, similar responses are also observed with tetraplegic individuals being under a much greater thermal strain than paraplegic individuals (Petrofsky 1992; Price & Campbell 2002). This is because of the level of lesion being above the sympathetic outflow, resulting in the absence or severe reduction of sweating capacity (Guttmann, Silver & Wyndham 1958). In relation to that, during exercise in the heat, paraplegic athletes demonstrates similar increase in core temperature compared with able-bodied athletes during arm crank ergometry (Price & Campbell 2002), but at a much lower metabolic rate, reflecting the decreased heat dissipation. The spinal cord population, especially those individuals with tetraplegic, may be considered to be at greater risk from heat-related illness than able-bodied individuals. When spinal cord injured subjects are cooled at rest, tetraplegic individuals demonstrate greater decreases in core temperature than paraplegic individuals and the able-bodied because of the lack of sympathetically induced vasoconstriction and an inability to generate larger amounts of metabolic heat from shivering as a result of paralysis (Downey, Chiodi & Darling 1967; Downey, Huckaba, Kelly, Tam, Darling & Cheh 1969; Guttmann, Silver & Wyndham 1958). It is possible that the absence of heat retaining mechanisms in tetraplegic individuals may enable a given cooling stimulus to be more effective than for paraplegic and able-bodied subjects and would have a significant impact on the reduction of heat injury in this population as well as improving the quality of life (Webborn, Price, Castle & Goosey-Tolfrey 2005).

### Cardiorespiratory fitness of wheelchair users

In recent years, interest in the physical capacity of persons with functional impairment of the lower part of the body and the legs has been increasing. Individuals who use wheelchairs vary widely in their level of cardiorespiratory fitness, some being seriously unfit and others are achieving levels that compare closely with those of fit able-bodied athletes. Zwiren and Bar-Or (1975) compared some 20 paraplegic and 21 able-bodied young men, using protocols involving exercise with an arm ergometer to submaximum and maximum levels. The subjects were grouped into 4 categories: WA (wheelchair active – 11 men who had lower limb disabilities for an average of 13 years but were training vigorously for international athletic competition), WS (wheelchair sedentary – 9 men who had lower-limb disabilities for an average of 7 years but undertook no physical training), NA (normal active – 13 able-bodied athletes who were members of a national team in sports that are related to the sports of the wheelchair athletes) and NS (normal sedentary – 8 able-bodied but sedentary young men). Results showed that the WA subjects were leaner compare to the WS subjects, that there were no intergroup differences of grip strength, that while the forced vital capacity (FVC) of the NA group was larger than that of all other groups, the mean FVC of the WA group was larger than that of the WS group and that there were no significant intergroup difference in maximum heart rate. The maximum heart rate intake of the WA subjects (expressed in milliliters of oxygen per kilogram of body weight per minute) was 9% lower than that of the NA group but 50% higher than that of the NS group.

Gass and Camp (1979) even reported that international-class Australian paraplegic athletes with lower-level lesions of the spinal cord had cardiorespiratory fitness levels compared to those of sedentary able-bodied subjects of similar age. More commonly fitness, as measured by maximum oxygen uptake of persons in wheelchair is low. This is usually because of unnecessary restrictions on their physical activity that can be associated with lack of opportunity or awareness (Zwiren & Bar-Or 1975; Wicks, Lymburner, Dinsdale & Jones 1978 ; Pollock, Miller, Linnerud, Laughridge, Coleman & Alexander 1974). Many persons with lower-limb disabilities, however are also restricted by physiologic disturbance, including a reduced maximum heart rate and a poor stroke volume in those with high-level of lesions. This can be associated with a loss of vasomotor regulation below the level of the lesion. The loss of venous return restricts the central blood volume and thus leads to poor cardiac performance (Smith, Guyton, Manniny & Whitey 1976). This also related to the arteriovenous oxygen difference at any given

submaximum work rate is unusually large in most lower limb disabled subjects (Hjeltnes 1977) , reflecting a poor regional blood flow to the active muscles, or a large amount of active muscle for the total blood flow available, or both.

Cardiorespiratory fitness assessment, whether maximal or submaximal, is a critical component in the development of an individual's exercise program. Exercise testing provides the clinician with baseline data that can be used to identify an individual's needs in order to develop an appropriate exercise program (Davis 1993). Standardized testing provides a tool to evaluate the effectiveness of the prescribed exercise program and gives the client motivating feedback. So, in relation to that, sub-maximal exercise testing has many advantages over maximal testing and is preferred by clinicians working with individuals with chronic pain or physical limitations, such as spinal cord injuries (Noonan & Dean 2000). Currently, there are a number of validated sub-maximal and maximal aerobic fitness tests designed for wheelchair users. Sub-maximal and maximal arm crank ergometry had been demonstrated to be a valid tool for assessing the cardiorespiratory fitness status of wheelchair users, but the arm cranking action is not functionally related to wheelchair mobility ( Davis 1993). Other tests, such as maximal and sub-maximal wheelchair treadmill tests and wheelchair ergometry based incremental speed tests, has also been shown to be valid and reliable (Hartung, Lahy & Blaneq 1993). However, all the tests must be done in a clinical or laboratory setting and this requires expensive equipment, trained administrators and is often time consuming.

Field tests for wheelchair users have been developed in an attempt to address some of these issues. The 12 minute Cooper test for distance, was adapted for wheelchair users and found to be well correlated ( $r=0.84$ ) to peak oxygen consumption ( $Vo_2$  peak) as determined by a typical laboratory based graded max arm ergometry test. Although this modified protocols developed by Franklin et al (1990) meets the requirements of a simple field test, self-paced tests for distance, regardless of the target population, are motivation dependent and previous experience will often influence the results (Franklin et al. 1990). A study by Vanlandewijck et al. (1990) used a wheelchair version the 25 m shuttle run 'beep test' and found that it correlated well ( $r= 0.78$ ) with peak heart rate (HR) measured in a maximal arm ergometry effort. Vint et al. (1996) found a moderate correlation ( $r= 0.65$ ) between laboratory derived  $VO_2$  peak and an increment field test using a 400 m tartan track. A multistage field wheeling test, a modified version of Leger and Boucher's (1980) continuous incremental running test, was developed and tested by

Vanderthommen et al. (2002). They found a moderate to high correlation between the distance covered during the shuttle wheel and the arm crank determined  $\text{Vo}_2$  peak and maximum power output ( $r=0.64$  and  $r=0.87$  respectively).. all the test require the maximal effort of the wheelchair users, so, a sub-maximal field test for wheelchair users that is easy to administer, potentially self-administered, time efficient, and requires minimal equipment, is necessary in order to provide safer and more reliable exercise prescriptions in the current health care environment (Luskin, Slivka & Frogley 2004)..

### **Wheelchair user's responses to training program using arm ergometer**

It is firmly established that average able-bodied adults can increase their cardiorespiratory fitness by 20% to 30% by participating in a well designed training program that involves the large muscles of the body (Gessaroli & Robertson 1980; Shepard 1965). The relative importance of the intensity, the duration and the frequency of training sessions has clarified by a number of experiments ( Astrand & Saltin 1961; McArdle, Glaser & Mayer 1971; Bar-Or & Zwiren 1975). Very less is known about the effectiveness of training using the arms only, and indeed, there is still an argument whether effective cardiovascular training can be induced by using arm effort (Vokac, Bell, Baultz-Holter & Rodahl 1975; Rasmussen, Klausen, Clausen & Trap-jens 1975; Clausen 1977).

Using arm crank ergometer for persons with paraplegia been often explained in various past studies. Emes compared the physical working capacity of 20 wheelchair and 20 able-bodied basketball players. The two groups did not differ significantly in their capacity to work with their upper trunk and arm muscles, as measured using an arm-crank ergometer, which suggest that the wheelchair athletes had adjusted relatively well to their disability. Even bar-Or and zwiren (1975) did also concluded that using their comparisons of paraplegic subjects at different fitness levels suggested that conditioning of the upper limb and trunk muscles was effective in increasing aerobic power, reducing the heart rate response to submaximum effort and controlling body weight. Nillson and associates (1975) found that after 7 weeks of training, subjects with paraplegia were able to perform an arm ergometer test at a maximum level with no more discomfort than able-bodied subjects. Their maximum oxygen uptake increased by 12% and they have enjoyed their training, that their feelings of confidence and well-being had increased, and that they had continued with the conditioning program after the formal part of the experiment has

ended. Pollock and associates (1974) studied the responses to training on an arm ergometer in two groups of former sedentary subjects and compared them with the responses of a third group that remained sedentary; the average age was 38 years in each group. Group 1 included 8 disabled individuals – 6 were in wheelchairs and 5 were completely paralysed from lower trunk down. Group 2 consists of 11 able-bodied men. Group 3 consisted of 10 able-bodied men, served as a control group. Groups 1 and 2 trained 3 times a week for 20 weeks. Although they showed no significant changes in girth or skinfold measurements, there was an increase in the maximum oxygen intake (19% in group 1 and 375 in group 2). The difference in training response was attributed to the differences in the intensity of conditioning activities that the 2 groups could perform. The able-bodied subjects were able to expend larger amounts of energy since they were able to obtain additional leverage from their leg muscle while working with their arm muscles.

### Specific overuse injuries in wheelchair sports

Many investigations and reports have described the type and frequency of injuries among individuals with spinal cord injury in various sports (table 1). The majority of these studies however are retrospective, involving either interviews or questionnaires. There has been no study published to date that looks specifically on overuse injuries in these individuals, mainly those who uses wheelchairs. Most sports-related injuries can be classified into one of two major types: acute macrotraumatic injuries, which are the result of a one-time in a event, or chronic microtraumatic injuries, which occurs over time and are often secondary to repetitive motions. Injuries in latter group (also referred to as overuse or overload injuries) made up to 50% of all sports –related injuries (Herring & Nilson 1987).

**Table 1:** Breakdown of 50 injuries reported by 19 elite wheelchair athletes over a 1-year period

Type of injuries	N	%
Strain	24	48
Abrasion	11	22

Contusion	5	10
Blisters	3	6
Fracture	3	6
Sprain	2	4
Laceration	1	2
Illness	1	2

*Source:* Bloomquist, L.E. (1986). Injuries to athletes with physical disabilities: prevention implications. *Phys Sports Med*: 14(9): 97-105.

Shoulder pain is quite common in persons with and without disabilities, who participate in sports, but it's very often seen in persons with wheelchairs. The reason is very clear because they rely entirely on upper limb for both ambulation and weight-bearing tasks most of the time. The shoulder, as we realize is poorly designed for this purpose, and becomes exposed to higher interarticular pressures related with a more abnormal distribution of stresses across the subacromial area. The shoulder joint has a greater range of motion than any other joint in the body. The radius of curvature of the humeral head is three times that of the glenoid socket (Howell & Galinar 1986). Unlike the hip joint, the shoulder relies on ligamentous and muscular components for its main constraints. A person who depends exclusively on a wheelchair for ambulation exposing his/her shoulders to increase stresses and muscular imbalances, predisposing it to a variety of overuse injuries. Participants in wheelchair sports, especially those involved in track events, marathon road racing, basketball and tennis, exposed their shoulders to even greater stresses, resulting in overuse problems.

Overuse injuries involving structures in and around the elbow joint are often seen in sport populations. Throwing and racquet based athletes are more susceptible to this type of injury, with lateral epicondylitis being the most common entity seen. Other common overuse injuries of the elbow region include: medial epicondylitis, entrapment of the ulnar nerve at the cubital tunnel and entrapment of the median nerve by pronator teres muscle. Several previous studies did mention about the common injuries that been highlighted in this population (Curtis 1982; Madorsky & Curtis 1984; Hoerberigs, Debets-Eggen & Debets 1990; Taylor & Williams 1995; Ferara, Buckley, McCann, Limbird, Powell & Robl 1992; Curtis & Dillon 1985; Nilsen, Nygard & Bjorholt 1985). The elbow, like the shoulders, is exposed to greater stresses and strains in

individuals who use wheelchair and is thus predisposed to injury. A study by Ferara et al. (1992) did clarify that 17% of the 100 injuries reported by 87 wheelchair users participating in sports, involved the elbow, with the vast majority of these being the overuse type. A study by Bloomquist (1986) did revealed that all wheelchair users participating in sports over the age of 40 reported elbow overuse problems.

Lateral epicondylitis, or most commonly been mentioned as tennis elbow is an overuse injury which involves the extensors of the wrist at their origin. The extensors carpi radialis brevis tendon is always affected. This is because of a repetitive microtraumatic overloading injury of the tissue, resulting from concentric and eccentric extensor muscle activity during rapid and stressful motions (Kibler 1995). The process is primarily degenerative, rather than inflammatory, and involves pathological changes within the tendon itself and not specifically the lateral epicondyle (Wiler 1994). Wheelchair tennis players develop lateral epicondylitis because of poor mechanics in overhand and backhand strokes, each which leads to either concentric or eccentric overloading of the wrist extensors at the elbow. Sports that engaged with wheelchair sports especially marathoners are exposed to the development of lateral epicondylitis. This is due to the repetitive hard and forceful elbow extension, performing maximal pronation and wrist flexion that are required during the wheelchair propulsion, which can leads to eccentric overloading of the wrist (Alley & Pappas 1995).

The repetitive stress of wheelchair propulsion predisposes the wrists of individuals who uses wheelchairs to a variety of overuse tendonitis injuries. This problems focused on wheelchair athletes since they generate speed through the larger forces ,a s well as the physical demands of their particular sports: improper pushing technique in which the wrists are in hyperflexion may eventually lead to wrist flexor tendonitis. In person who participates in wheelchair racing, there may be a repetitive hyperpronation of the forearm during the end of the propulsion cycle, which may eventually lead to the development of specific wrist tendonitis entities as well as lateral epicondylitis (Busconi & Curtis 1995). Usually, the injured wrist tendons in wheelchair users who participated in sports include: extensor digitorum longus, extensor carpi ulnaris, flexor carpi ulnaris and abductor policis longus (Busconi & Curtis 1995).

Carpal tunnel syndrome (CTS) is caused by a compression of the median nerve as it transverse the carpal tunnel. There are various cause have been linked to the syndrome such as diabetes mellitus, pregnancy, hypothyroidism, rheumatoid arthritis, ganglion cysts, osteoarthritis and



flexor tendonitis. Wheelchair users with paraplegia have been reported to have an increased incidence as compared to the non-disabled population (Aljure, Eltorai, Bradley, Lin & Johnson 1985; Gellman et al. 1988). Study by Gellman et al. (1988) found that the carpal tunnel pressure of persons with paraplegia was significantly elevated in wrist extension as compared to individuals without paraplegia. Burnham et al. (1994) also did a study related to injuries to CTS revealed a significant showing of median nerve conduction velocities across the carpal tunnel immediately after the subjects propelled a wheelchair. Burnham and Steward (1994) reported a 46% incidence of CTS by electrodiagnostic criteria in 28 sports participants who are wheelchair users, with a substantially lower number of these patients having clinical evidence of CTS. One reason that linked to this syndrome is the repetitive extrinsic pressures over the carpal tunnel as well as frequent wrist extension posturing, both of which occur during wheelchair propulsion. An observation revealed that most of them handle the push rims with their thumbs, but when they are tired, they switch to their palms, placing more stress on the carpal tunnel (Ferara & Davis 1990). Another reason is when the repetitive strain and overuse of the wrist flexor tendons, which is commonly experienced by the wheelchair athletes, can lead to inflammation which may affect the median nerve in the carpal tunnel (Burnham & Steward 1994).

### **Wheelchair athletes and upper body strength considerations**

The shoulder complex participates in many daily activities. For the wheelchair-bound paraplegic, the scapulohumeral joint is particularly used for repetitive movements and thus undergoes considerable muscle-joint stress (Bernard, Codine & Minier 2004). Wheelchair propulsion and depression transfers require adaptations of all the particular structures, which were originally developed for prehension or balance. Several studies have reported kinematic analysis of propulsion (Dednarczyk 1994; Kulig et al. 1998; Van der Woude, Van Kranen, Ariens, Rozendhal & Veeger 1995) and the muscular activity during the propulsion cycle (Mulroy, Gronley, Newsam & Perry 1996; Ryu, McCormick, Jobe, Moynes & Anatonelli 1988). The isokinetic method of exercise and the agonist/antagonists ratio, which have been useful in studies to prevent dysfunction, are two methods in understanding the muscular adaptations that occur with athletic activities (Hinton 1988; McMaster, Long & Caiozzo 1991; Wilk, Andrews, Arrigo, Keirns & Erber 1993).

Eklblom and Lundberg (1968) did a study on 24 adolescent subjects with lower-limb disabilities. The training regimes would be the usual required physical education class (two or three periods

in the gymnasium each week) with an additional of two 30-minute training sessions each week. The supplementary sessions included 2 to 5-minute bursts of large muscle activity, such as propelling the wheelchair rapidly or using medicine balls, dumbbells and parallel bars. Unfortunately only 8 (most probably the fittest) of the subjects were able to complete all the tests. The post test revealed that a 40% increment in work tolerance, mechanical efficiency and a reduction in the extent to which lactate accumulated in the blood during submaximum work.

Despite the above study, there have been few studies of strength training for wheelchair users. Stoboy and Wilson-Rich (1971) reported some measurements of isometric strength in disabled subjects, and even Nilson and associates (1975) included assessments of triceps strength in paraplegic subjects after a 7-week training program. The data don't really showed a great changes specifically in the triceps, but they did showed the overall dynamic strength and muscular endurance were increased 19% and 80% respectively after the training.

Wheelchair users should be encouraged to use a hand-propelled rather than a motorized chair in daily life and to eat a diet that is well regulated to avoid accumulation of excess body fat. They too should understand the normal wheelchair activity about the environment in the house produce less training to maintain cardiovascular fitness because the work load during wheelchair ambulation is thrown on just a small portion of muscle groups, and their heart rate during movement is an adequate guide to training intensity.

### Conclusion

The intensity of the cardiovascular stimulus can be adjusted by regulating the length of the activity and recovery phases. The aim should be for the disabled person to complete at least four 30-minute exercise sessions each week, during which the hart rate, assessed immediately after they stop exercising, has been increased to 60% of the difference between the rate at rest and the age-related maximum rate; that is, in an individual with a maximum heart rate of 180 beats/min and a resting rate of 80 beats/min, the heart rate immediately after they stop exercising should be 140 beats /min. In individuals who have been in hospital or very sedentary for a number of years, a gradual progression in the number, duration and the intensity of exercise sessions is vital to success. Besides, the danger that exercisers may suffer physical injury if they attempt to progress too rapidly, they may also become convinced that the program is too strenuous or that they

cannot succeed with it. With the combination of a resolute patient and a gentle but persistent therapist, many wheelchair users can ultimately adjust relatively well to their disability.

The treatment and rehabilitation of overuse injuries to the upper limbs of this population of wheelchair users can be difficult since these individuals rely almost exclusively on their upper limbs for both mobility and weight-bearing tasks. Both consideration of physical findings and biomechanical errors or deficiencies must be addressed in order to ensure full recovery and/or prevent recurrence.

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