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Artikel Review

# Wheelchair Athletes and Their Considerations in Sporting Activities

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**Abstract** Wheelchair athletes need to engage into physical activity and sports in order to keep their body functioning for activity for daily living (ADL) or for sporting actions. Sports also are a part of the rehabilitation program since it been introduced by Sir Ludwig Gutmann in England late 1940s. With the growth of sport activity in daily lives of persons with disabilities, it has been rightly perceived that disabled persons could obtain the same physical and emotional benefits from sport as their able-bodied counterparts, leading to an increased need to overcome limitations, opponents and records. The introduction of sports therapy in rehabilitation, as well as further involvement in sports depends on the severity of the injury, might lead a disabled person to either become a non-competitive athlete or a paralympic athlete. Athletes with Spinal cord injury facing problems with their thermoregulatory response. In relation to that, during exercise in the heat, paraplegic athletes demonstrates similar increase in core temperature compared with able-bodied athletes, but at a much lower metabolic rate, reflecting the decreased heat dissipation. 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. Wheelchair users also 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.

**Keywords:** physical activity; sports; wheelchair users; spinal cord injury

## INTRODUCTION

To achieve success in life and in sports, athletes with disability must have a combination of hard work, methods of training, sacrifice and determination, incentive and opportunity England (Steward & Peterson, 1997). This is particularly important for disabled athletes spinal cord injuries or amputations, which usually led to permanent inability or death until few decades ago. It was only after the Second World War that their situation improved in terms of opportunities available for them to participate in sport (Steward & Peterson, 1997). Overall, also, the increase in number of disabled person's participating in sport was stimulated by the creation of the rehabilitation centers in the United States and England (Steward & Peterson, 1997).

The work of Dr. Ludwig Guttmann is particularly noteworthy in the opening of access for disabled persons to participate in sports. In fact, it was ho Dr. Ludwig Guttmann, who pioneered 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, a neurologist who had escaped from the Nazi persecution of Jews in Germany, created the National Centre to Spinal Cord Injury at the Stoke Mandeville Hospital to treat injured British soldiers from Second World War. The treatment allowed them to participate in sport. The pioneering work of Dr. Ludwig Guttmann was followed in the United States and Germany. In 1948 this concept of introducing sports for injured people achieved an official status with the first international competition for disabled athletes at the Stoke Mandeville games.

With the growth of sport activity in daily lives of persons with disabilities, it has been rightly perceived that disabled persons could obtain the same physical and emotional benefits from sport as their able-bodied counterparts, leading to an increased need to overcome limitations, opponents and records (Kottke & Lehman, 1994). Part of therapy techniques that been introduced for the treatment for persons with disabilities, and the use of advanced technologies, in sports activities constitute

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important mediums for the rehabilitation and reintegration of persons with disabilities into sport and ultimately into society (Kottke & Lehman 1994). The introduction of sports therapy in rehabilitation, as well as further involvement in sports depends on the severity of the injury, might lead a disabled person to either become a non-competitive athlete or a paralympic athlete (Kottke & Lehman 1994).

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 ergometery (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).

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 higher 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 submaximal 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 submaximal 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 (Vo2 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 of 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 VO2 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 shuutle wheel and the arm crank determined Vo2 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).

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.

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 (Herring & Nilson, 1987). 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 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 injuries0 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 realizes 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; Hoeberigs, 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 reveal that all wheelchair users participating in sports over the age of 40 reported elbows 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 use wheelchairs to a variety of overuse tendonitis injuries. This problem focused on wheelchair athletes since they generate speed through the larger forces, as 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 digitorium 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 disbetes melilitus, 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).

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).

Ekblom and Lundberg (1968) conducted a study on 24 adolescent subjects with lower-limb disabilities. The training regimes were 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 per minute and a resting rate of 80 beats per minute, the heart rate immediately after they stop exercising should be 140 beats per minute. 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.

## REFERENCES

Aljure, J., Eltorai, I., Bradley, W.E., Lin, J.E., Johnson, B. 1988. Carpal tunnel syndrome in paraplegic patients. *Paraplegia,* 23: 182-6

Alley, R.M., Pappas, A.M. 1995. *Acute and chronic performance related injuries of the elbow*. In: Pappas, A.M. ed. Upper extremity injuries in the athlete. New York: Churchill Livingstone, 349

Astrand, P.O., Saltin, B. 1961. Maximal oxygen uptake and heart rate in various types of muscular activity. *J Appl Physiol.* 16: 977-981

Bar-Or, O., Zwiren, L.D. 1975. Jmaximal oxygen consumption test during arm exercise-reliability and validity. *J Appl Physiol*. 38: 424-426

Bernard, P.L., Codine, P., Minier, J. 2004. Isokinetic shoulder rotator muscles in wheelchair athletes. *Spinal Cord.* 42: 222-229

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

Burnham, R.S., Steadward, R.D. 1994. Upper extremity peripheral nerve entrapments among the wheelchair athletics: prevalence, location, and the risk factors. *Arch Phys Med Rehabil*. 75:519-24

Busconi, B.S., Curtis, K.A. 1995. *Physically challenged athletes*. In: Pappas, A.M, ed. Upper extremity injuries in the athlete. New York: Churchill-Livingstone, 101-16.

Claussen, J.P. 1977. The effect of physical training on cardiovascular adjustments to exercise in man. *Physiol Rev.* 57: 779-815

Curtis, K.A. 1982. Wheelchair sports medicine, part 4: Athletic injuries. *Sports N Spokes*. Jan-Feb: 20-4

Curtis, K.A., Dillon, D.A. 1985. Survey of wheelchair athletic injuries: common patterns and prevention. *Paraplegia,* 23: 170-5

Curtis, K.A., Steward, R.D., Weiss, M.C. 1990. Impairment no barrier to fitness. *Patient Care*. 15: 130-143

Davis, O.M. 1993. Exercise capacity of individuals with paraplegia. *Med Sci Sports Exerc,* 25(4): 423-432

Dednarczyk, J.M. 1994. Kinematics of wheelchair propulsion in adults and children with spinal cord injury. *Arch Phys Med Rehab,* 75: 1327-1333

Downey, j.A., Chiodi, H.P., Darling, R.C. 1967. Central temperature regulations in the spinal man. *J Appl Physiol* 22: 91-94.

Downey, J.A., Huckaba, C.E., Kelley, P.S., Tam, H.S., Darling, R.C., Cheh, H.Y. 1969. Thermoregulatory responses to deep and superficial cooling in man. *J. Appl Physiol.* 27: 209-212

Ekblom, B., Lundberg, A. 1968. Effects of physical training on adolescents with severe motor handicaps. *Acta Paediatr Scand.* 57: 17-23

Emes, C. *Physical Work Capacity of Wheelchair Athletes*. Ibid: 209-212

Ferara, M.S., Buckley, W.E., McCann, B.C., Limbird, T.J., Powell, J.W., Robl, R. 1992. The injury experience of the competitive athlete with a disability: prevention implications. *Med Sci Sports Exerc,* 24: 184-88

Ferara, M.S., Davis, R.W. 1990. Injuries to elite wheelchair athletes. *Paraplegia,* 28: 335-341

Franklin, B.A., Swantek, K.I., Grais, S.L., Johnstone, K.S., Gordon, S., Timmis, G.C. 1990. Field test estimation of maximal oxygen consumption in wheelchair users. *Arch Phys Med Rehabil*, 71(8): 574-578

Gass, C.G., Camp, E.M. 1979. Physiological characteristics of trained paraplegic and tetraplegic subjects. *Med Sci Sports*. 11: 256-259

Gellman, H. et al. 1988. Carpal tunnel syndrome in paraplegic patients. *J. Bone Joint Surg.* 70A(4): 517-9

Gessaroli, M.E., Robertson, D.G.E. 1980. Comparison of two wheelchair sprint starts (abstr). *Can J Appl Sports Sci* 5

Guttmann, L., Silver, J., Wyndham, C.H. 1958. Thermoregulation in spinal man. *J Physiol.* 142: 406-419

Hartung, G.H., Lahy, D.A., Blaneq, R.J. 1993. Comparison of treadmill exercise testing protocols for wheelchair users. *Eur J Appl Physiol Occup Physiol.* 66: 362-365

Herring, S.A., Nilson, K.L. 1987. Introduction to overuse injuries. *Clin Sports Med.* 6(2): 225-39

Hinton, R.Y. 1988. Isokinetic evaluation of shoulder rotational strength in high school baseball pitchers. *Am J Sports Med* 16: 274-279

Hjeltnes, N. 1977. Oxygen uptake and cardiac output in graded arm exercise in paraplegia with low level spinal lesions. *Scand J Rehabil Med*. 9: 107-113

Hoeberigs, J.H., Debets-Eggen, H.B.L., Debets, P.M.L. 1990. Sports medical experiences from the international flower marathon for disabled wheelers. *Am J Sports Med.* 18(4): 418-21

Howell, S.M., Galinar, B.J. 1986. The glenoid labral socket: a constrained articular surface. *Clin Orthop.* 243: 122-35

Kibler, W.B. 1995. Pathophysiology of overload injuries around the elbow. *Clin Sports Med*. 14(2): 447-57

Kottke, F.J.,lehmann, J.F. 1994. *Manual De Medicina Do Fisica De Reabilitacao*. 4th ed. Sao Paulo: Manole.

Kulig, K. *et al*. 1998. Shoulder joint kinetics during push phase of wheelchair propoulsion. *Clin Orthop.* 354: 132-143

Laskin, J.J., Slivka, D., Frogley, M. 2004. A cadence based sub-maximal field test for the prediction of peak oxygen consumption in elite wheelchair basketball athletes. *J Exerc Physiol.* 7(1): 8-18

Leger, l., Boucher, R. 1980. An indirect continuous running multistage field test: The Universite de Montreal track test. *Can J Appl Sport Sci.* 5(2): 77-84

Madorsky, J.G.B., Curtis, K.A. (1984). Wheelchair sports medicine. *Am J Sports Med.* 12(2): 128-132

Mc Master, W.C., Long, S.C., Caiozzo, V.J. 1991. Isokinetic troque imbalance in rotator cuff of elite water polo players. *Am J Sports Med,* 19: 72-75

McArdle, W.D., Glaser, R.M., Mayel, J.R. 1971. Metabolic and cardiorespiratory response during free swimming and tredmill walking. *J Appl Physiol.* 30: 733-738

Mulroy, S.J., Gronley, J.K., Newsam, C.J., Perry, J. 1996. Electromyographic activity of shoulder muscles during wheelchair propulsion by paraplegic persons. *Arch Phys Med Rehabil.* 77: 187-193

Nilsen, R., Nygaard, P., Bjorholt, P.G. 1985. Complications that may occur in those with spinal cord injuries who participate in sport. *Paraplegia.* 23:152-8

Nilsson, S., Staff, P., Pruett, E. 1975. Physical work capacity and the effect of training on subjects with long standing paraplegia. *Scand J Rehabil Med.* 7: 51-56

Noonan, V., Dean., E. 2000. Submaximal exercise testing: clinical application and interpretation. *Phys Ther,* 80(8): 782-807

Petrofsky, J.S. 1992. Thermoregulatory stress during rest and exercise in heat in patients with a spinal cord injury. *Ear J Appl Physiol.* 64: 503-507

Pollock, M., Miller, H., Linnerud, A., Laughridge, E., Coleman, E., Alexander, E. 1974. Arm pedaling as an endurance training regimen for the disabled. *Arch Phys Med Rehabil.* 55: 418-424

Price, M.J., Campbell, I.G. 2002. Thermoregulatory responses of able-bodied, upper body trained athletes to prolonged arm crank exercise in cool and hot conditions. *J Sports Med.* 20: 457-463

Price, M.J., Campbell, I.G. 2003. Effects of spinal cord lesion level upon thermoregulation during exercise in the heat. *Med Sci Sports Exerc.* 35: 1100-1107

Rasmussen, B., Klausen, K., Clausen, J.P., Trap-Jens, J. 1975. Pulmonary ventilation, blood gases, and blood pH after training of arms and legs. *J Appl Physiol.* 38: 250-256

Ryu, R.K., Mc Cormick, J., Jobe, F.W., Moynes, D.R., Anatonelli, D. An electromyographic analysis of shoulder function in tennis players. *Am J Sports Med.* 16: 481-485

Shepard, R.J. 1965. The development of cardiorespiratory fitness. *Med Serv J Can.* 21: 533-544

Shepard, R.J. 1977. *Endurance fitness*, 2nd ed. U of Toronto Pr, Toronto.

Smith, E.E., Guyton, A.C., Manniny, R.D., Whitey, R.J. 1976. Integrated mechanism of cardiovascular response and control during exercise in the normal human. *Prog Cardiovasc Dis.* 18: 421-443

Steward, R.D., Peterson, C. 1997. *Paralympics where heroes come*. Canada:dw friezes Ltda.

Stoboy, H., Wilson-Rich, B. 1971. Muscle strength and electrical activity, heart rate and energy cost during isometric contractions in disabled and non-disabled. *Paraplegia.* 8: 217-222

Taylor, D., Williams, T. 1995. Sports injuries in athletics with disabilities: wheelchair racing. *Paraplegia* . 33: 296-9

Van der Woude, L.H., Van Kranen, H., Ariens, G., Rozendhal, R.H., Veeger, H.E. 1995. Physical strain and mechanical in hubcrank and handrim wheelchair propulsion. *J Med Eng Technol*, 19: 123-131

Vanderthommen, M., Francaux, M., Colinet, C., Lehance, C., Lhermerout, C., Criellard, J.M., Theissen, D.A. 2002. Multistage field test of wheelchair users for evaluation of fitness and prediction of peak oxygen consumption. *J Rehabil Res Dev* 39(6): 685-692

Vanlandewijck, Y.C., Daly, D.J., Theisen, D.M. 1990. Field test evaluation of aerobic anaerobic and wheelchair basketball skill performances. *Int J Sports Med.* 20(8): 548-554

Vinet, A., Bernard, P.L., Poulain, M., Varray, A., LeGallais, D., Micallef, J.P. 1996. Validation of an incremental field test for the direct assessment of peak oxygen uptake in wheelchair dependent athletes. *Spinal Cord.* 34(5): 288-293

Vokac, Z., Bell, H.J., Bautz-Holtes, E., Rodahl, K. 1975. Oxygen uptake / heart rate relationship in leg and blood pH after training of arms or legs. *J Appl Physiol.* 38: 54-59

Webborn, N., Price, M.J., Castle, P.C., Goosey-Tolfrey, V.L. 2005. Effects of two cooling strategies on the thermoregulatory responses of tetraplegic athletes during repeated intermittent exercise in the heat. *J Appl Physiol.* 98: 2101-2107

Wicks, J., Lymburner, K., Dinsdale, S., Jones, N. 1977-78. The use of multistage exercise testing with wheelchair ergometry and arm cranking in subjects with spinal cord lesions. *Paraplegia.* 15: 252-261

Wilder, R.P., *et al.* 1994. *Elbow and forearm*. In: Buschbacher R.M., ed. Musculoskeletal disorders: a practical guide for diagnosis and rehabilitation. Stoneham, MA: Butterworth-Heinemann: 163-9

Wilk, K.E., Andrews, J.R., Arrigo, C.A., Keirns, M.A., Erber, D.J. 1993. The strength characteristics of internal and external rotator muscles in professional baseball pitchers. *Am J Sports Med* 21: 61-66

Zwiren, L., Bar-On, O. 1975. Responses in exercise of paraplegics who differ in conditioning level. *Med Sci Sports* 7: 94-98