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INJURIES TO WHEELCHAIR ATHLETES: THROUGH SPORT PARTICIPATION, TRAINING, AND COMPETITION

by

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The undersigned certify that they have read, and recommend to the FACULTY OF GRADUATE STUDIES AND RESEARCH, for acceptance, a thesis entitled INJURIES TO WHEELCHAIR ATHLETES: THROUGH SPORT PARTICIPATION, TRAINING, AND COMPETITION submitted by D. A. REBECCA McCORMACK in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in SPORTS INJURY/ADAPTIVE PHYSICAL EDUCATION.

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Abstract

Sports medicine has recieved a considerable amount of attention in recent years. Unfortunately, a limited amount of sports injury information is available in wheelchair sports. The purpose of this study was to provide a profile of wheelchair athletes' injuries through participation, training or competition in wheelchair sports.

An original questionnaire was administered to Canadian wheelchair athletes at 4 games in Canada throughout the summer of 1985. The results indicated that the most common injuries were blisters (23.2%), abrasions (21.5%), muscle strains (16.3%), and tendinitis (9.3%). Eighty percent (80%) of the 90 athletes competed in an average of 5 competitions per year, in 35 different sports. The modal level of training was 6 to 10 hours per week. The high participation sports were also the sports with the highest injury incidence rates: basketball (1.91/participant), road racing (1.17/participant), rugby (1.14/participant), and track events (1.12/participant). The hands (20%), shoulders (15.5%), fingers (11.8%), and arms (10%) were the body parts most commonly injured. Of all disability groups, the 'les autres' had the highest injury incidence. Although 72% of athletes wore protective equipment, most (60%) wore gloves, leg straps (23.3%) or arm bands (8.9%). One quarter (25%) of wheelchair athletes received no treatment for their injuries and less than one third (30.8%) sought medical aid or advice.

This etiological research study provides basic descriptive information on wheelchair sports injury that is valuable to wheelchair athletes, coaches, sports medical personnel, and interested others. Its contribution to disabled sports will be recognized as an initial pioneering effort to establish a basic framework for future, scientifically sound studies in wheelchair sports medicine.

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Table of Contents

List of Tables

List of Figures

List of Plates

Chapter I

Introduction

> If you treat a man as he is, he will remain as he is. If you treat a man as he should and could be, he may become as he should and could be. Never underestimate another's potential for no man has the right to set limitations and restrictions on another man's potential.
> (Anon).

A. History

In the long history of competitive athletics, sports for the physically challenged are a recent development. After World War II, the sudden rise in the number of disabled war veterans forced the medical world to be more attentive to the demands and rehabilitative needs of amputees and spinal-cord injured individuals (Grosfield, 1985). Prior to WWII, little time was spent on the rehabilitation of disabled people; "the sooner they died, the better for all concerned" (Goodman, 1986, p.97). There were fewer disabled persons, and the prevailing attitude towards them was negative. Society viewed these people as incapable of ever fully developing their potential. This negative philosophy was so strong that traditional thinking accepted that spinal cord injured people should pass their time "sitting in a wheelchair waiting for death while their bodies and spirits wasted away"(Diamond and McKeown, 1985). Spinal paraplegics and quadriplegics were considered hopeless cripples with short lifespans (Guttmann, 1976). Before the discovery of antibiotics and the advancements in modern medicine, a spinal-cord injury was "virtually a death sentence"(Ross, Cosbie, and Harris, 1980; in Pool and Tricot, 1984). As quoted from Wagner and Stopler, two respected German physicians at the turn of the century,

> severe spinal-cord injury is the physician's forlorn task, even while knowing that the patient is approaching an early death, to keep them alive for weeks and months on end, only to see them wretchedly fade away despite all skill and efforts (Goodman, 1986 p.97).

Up to and during WW II paraplegia was the most depressing and neglected subject of all medicine, and it was regarded by doctors with "profound pessimism" (Goodman, 1986, p.98). The medical profession's greatest concern, with regards to spinal cord injuries, was their many life-threatening medical complications. Those who survived the mental anguish and despair died from serious medical ailments including decubitus ulcers (advanced pressure sores), urinary psepsis, kidney disorders, and severe lung infections (Guttmann, 1976). Medical assistance for spinal-cord injured people was limited to coping with their basic survival needs.

For many spinal-cord injured people of WW II era, the challenge of survival was inconceivable. Overcome by society's negative attitude, their own lack of self-esteem, the omnipresence of severe medical complications, and an archaic approach toward rehabilitation, it was not surprising that the majority of individuals with spinal-cord injury died within weeks of their initial trauma. During WW II, young paraplegic casualities were given two to three years to live from the onset of spinal-cord injury, some as little as six weeks. The following is an account of the acute medical management of a paraplegic of the WWII era in England.

> A well built, over six foot tall young coal miner was admitted with a broken back and complete paraplegia below the waist. After manual relocation of the spine the patient was put into a plaster body cast. Thereafter, the patient was transferred to the surgical ward and screened off from other patients. According to the attending surgeon, that 'man would be dead in six weeks at the latest' (Goodman, 1986, p.28). Over the following weeks that fine, strong man was seen to have rapidly deteriorated in health, to have become increasingly emaciated, and died just five weeks after his injury as a result of psepsis from an urinary infection (Goodman, 1986, p.28).

Compared to the lifespan of the spinal-cord injured in the WWII era, the mortality rate of the spinal-cord injured during WWI (1914-18), three decades earlier, was even higher. According to Thompson and Walker (1937) 80% of Britain army personnel who sustained spinal-cord injuries in WW I died after three years (Goodman, 1986, p.9). Such was the prognosis of the spinal-cord injured.

This negative attitude toward the spinal-cord injured, their high mortality rate, and the crude form of medical management provided to these disabled individuals resulted in a dim outlook. Their focus was not much beyond basic survival. According to Maslow, a well-known psychologist, the basic biological needs for survival include hunger, pain avoidance, affection, security, and self-esteem (Gatchel and Mears, 1982, p.430). In the presentation of his influential phenomenological theory of self-actualization, Maslow argued that "full development of an individual involves self-actualization, or achieving fulfillment of one's inhe[illegible] potentials"(Gatchel and Mears, 1982, p. 432). This universal drive to self-actualization is realized through the hierarchial fulfillment of goals (Figure A.1 in Appendix A). In his pyramid model, basic survival needs form the groundwork for the achievement of meta- goals. Maslow's prescribed means of mobility within this framework was vertically. Therefore, only when these basic needs had been satisfied could an individual pursue further meta-goals.

The disabled individual in pre-WWII society did not rise vertically through any of Maslow's hierarchial levels as illustrated in Figure A.1 (Appendix A). The prime focus of disabled people was physical survival and daily living. According to Maslow's model, disabled people would have to achieve all of these 'basic needs' at the primary level of the framework, before energy could be focused on achieving greater hierarchial goals. Thus, within the pre-WWII framework, it was impossible for the disabled individual to realize higher hierarchial needs.

B. Present Day Philosophy: Rehabilitation

However, three factors concomitantly contributed to a change in society's outlook toward the disabled person, and, latently, to the increased lifespan of the disabled individual. First was the overwhelming number of war veterans disabled in combat. Society could not shun the war wounded; those with amputations, spinal-cord injuries and other service-related casualities had fought for their country. Hence, a new respect for disabled people evolved.

The second were the advancements in modern medicine and the discovery of ıtibiotics. Prior to this great medical progress, an injury to the spinal cord was "virtually a death sentence"(Ross, Cosbie, and Harris, 1980; in Pool and Tricot, 1984). Those who survived the mental anguish and despair of their disability, died from serious medical complications. Physically, the initial trauma to the spinal cord that resulted in partial or complete paralysis was so great that wheelchair-bound people had little hope of survival. Once moderm medicine and antiobiotic drugs were able to control some of these physical complications, the lifespan of disabled people increased. Medical attention could then be focussed on the rehabilitation of these people, an area where little progress had been made.

The third factor that contributed to the acceptance of disabled people by society was the introduction of athletics into the rehabilitation process by an European neurosurgeon, Sir Ludwig Guttmann. In 1944, the British government commissioned, and later knighted, Ludwig Guttmann, a Jewish doctor who escaped the Nazis in the 1930's, as Medical Director of a special unit at the Stoke-Mandeville Hospital in England. His responsibilities included caring for those disabled in the war. He specialized in work dealing with spinal-cord injured people. Rehabilitation of the great numbers of war veterans, who had become severely disabled quadriplegics and paraplegics in WWII, was the primary reason for the opening of this centre.

As a rehabilitation center, the accepted objectives were to encourage disabled people to make maximum use of their remaining functions and to obtain the highest degree of independence permitted by their disability (Burke and Murray, 1975). To achieve this independence, it was necessary to create a positive self-image by the promotion of ego, feelings of self-worth, and greater self-esteem. To foster the growth of this new self-image, rehabilitation must acknowledge the intricate relationship between mind and body (Schlenoff, 1980, p.76). Thus, the emphasis of the rehabilitation process must be on the person's capabilities not on the disease. For, as McCann remarked, "it is not what you have lost, but what you have left that counts"(McCann, 1981 p.46).

Conventional rehabilitation methods had not included recreation or sports. The traditional passive approach towards rehabilitation mostly involved gentle massage techniques (Goodman, 1986). Many of the methods were found by to be "outdated and inadequate" (Goodman, 1986, p.111). Guttmann's philosophy toward the management of the spinal-cord injured was fundamentally different. He masterminded today's concept of total care for the spinal-cord injured patient. He wished to provide a comprehensive medical service to "rescue paraplegics and quadriplegics from the human scrapheap and to return them ... to a life worth living, as useful and respected citizens in the community" (Goodman, 1986, p.99). Thus Guttmann's approach was at variance with the prevailing attitudes of the pre-World War II medical community.

C. Wheelchair Sports: Their Beginning

According to Guttmann, the grandfather of wheelchair sports, "nowhere could the philosophy of modern rehabilitation, its objectives, aims, and goals find a better application and justification than in sports"(Guttmann, 1976). That sports and exercise are beneficial has been an accepted fact since the time of Galen and Maimonides in the Second Century B.C.. For "anyone who lives a sedentary life and does not exercise even if he eats good food and takes care of himself according to proper medical principles - all his days will be painful ones and his strength shall wane"(Goodman, 1986, p.144). The great advantage of sports over formal remedial exercise, perhaps of the variety entertained by the Greeks, lies in its recreational value. More than formal exercise, sports restore the passion for playful activity and the desire to experience the joys and pleasures of life. At the Stoke-Mandeville Centre, in February, 1944, Guttmann was given the opportunity to pursue his interest and dream of sports participation by disabled people (Goodman, 1986, p. 101). It was at Stoke, that his radical views toward the treatment of the spinal-cord injured were first put into practice.. Appropriately, it was also at Stoke Mandeville that wheelchair sports competition began. To Guttmann, sports represented the most natural form of remedial exercise; one whose benefits are of significant therapeutic, recreational, psychological, and social value. Not only did sporting activities have all the components of physical development, they provided competitive challenges, built self-esteem, and "relieved the boredom of hospital life" (Guttmann, 1976).

Guttmann appreciated the qualities of sports which develop courage, emulation, and the greater excellence of oneself (Pool and Tricot, 1984). In essence, he utilized sport to help the disabled people's upward mobility, within Maslow's hierarchy, toward the ultimate goal of self-actualization or the achievement of psychological, social, mental, and physical well-being. He advocated that, "the most effective way to prepare anyone for ... society is to get them actively involved in developing their strengths" (Guttmann, 1976). These strengths, he felt, could be rediscovered through active involvement in recreational and sporting endeavours. Sporting activities, he claimed, "have all the components of physical development, competitive challenges, and self-esteem building" (Guttmann, 1976, p.12).

D. Competitive Sports Involvement

Prior to the 1940's, no disabled person, either paralyzed or amputee, had formally participated in recreational or sporting pursuits. While able-bodied athletes competed in the Olympic Games, the spinal paraplegics and quadriplegics were considered hopeless cripples with short lifespans (Guttmann, 1976). As Anderson stated, "it is not often enough in rehabilitation that the higher goals which might permit the disabled person to participate in sports or recreation are considered" (Anderson, 1984, p.57). This non-participation in recreational pursuits by the disabled continued until July 28, 1948 when Guttmann introduced competitive wheelchair sports. On the grounds of the Stoke-Mandeville Hospital in Aylesbury, England, 16 war veterans gathered to compete in the first documented, organized athletic archery competition for disabled persons. Never before had disabled persons competed as athletes in their own right. Through competition, the disabled were provided with the opportunity to learn the life of an athlete, the love of sweet victory, the agony of defeat, the hard work and dedication needed to endure long hours of training, and the unfortunate omnipresence of sports injuries. Through wheelchair sports, disabled athletes exercised their rights to accept the challenges and risks of athletics in the same manner as their able-bodied counterparts (Corcoran et al, 1980).

Introduced as a part of the medical rehabilitation treatment for paraplegic and quadriplegic war veterans (Guttmann, 1976; Nilsen, 1985), sports became more than just a means to combat the boredom of hospital life. Four years after the first athletic archery competition on the lawn of the Stoke-Mandeville Hospital in 1948, the event became an annual international meet named the Stoke-Mandeville Games. The creed of these Games is;

> to unite paralysed men and women from all parts of the world in an international sports movement,... {through the} spirit of true sportsmanship...{to} give hope and inspiration to thousands of paralysed people {and} to further friendship and understanding among nations (Pool and Tricot, 1984).

Disabled people utilized sporting competition to raise themselves out of their "destitute moral condition" (Pool and Tricot, 1984). Through Guttmann's encouragement, persistence, and philosophy, the disabled had conceptually applied sports to Maslow's hierarchy of self-actualization to rise vertically toward the fulfillment of their own potentials. As the disabled began proving their ability to obtain vertical mobility, without the full completion or achievement of each of Maslow's horizontal levels, disabled individuals appeared in higher educational institutions, in the work force and in international sports competitions.

E. Wheelchair Athletes: Acceptance & Integration

Inretrospect, the past 4 1/2 decades have witnessed a dramatic increase in the lifespan of the physically challenged, a change in attitude of the medical environment from neglect and pessimism to a focus on total rehabilitation of the physically challenged, and an overwhelmingly positive response to sports participation by the physically challenged. These outcomes are the ramifications of Guttmann's noteworthy, dedicated lifetime of work as a neurosurgeon, and his radical approach to rehabilitation. Sports for disabled people has become a means for enjoyment, a latent means of acceptance for disabled people, and an arena for improved performances.

Since the time of its formal inception in 1948, wheelchair sports have evolved to their present day international popularity and world class reputation. The recent rise in the number of spinal-cord injured involved in sports and recreation is a reflection of both the increase in accidents causing injury to the head, neck, spine in our industrialized society, and the increasing lifespan of spinal-cord injured people (Tan, 1985, p.159). Dr. Robert Hansebout (1985) believed that spinal-cord injuries have reached epidemic proportions (Hansebout, 1985; in Diamond and McKeown, 1985). In 1985, more than 300,000 North Americans were confined to wheelchairs as victims of spinal-cord injury (Tan, 1985; Diamond and McKeown, 1985). The continued occurrence of disabling injuries to the spinal-cord and the increased lifespans of spinal-cord injured people results in many disabled people with leisure time. Many of today's disabled people have chosen sports and recreation as a fitness venture, a recreational past time, or for a competitive challenge.

The increased popularity of competitive wheelchair sports events can be measured by the attendance of athletes at the competitions. In 1948, 16 disabled men and women competed in the first wheelchair sports competition held in England (Goodman, 1986, p.149). Nearly one quarter of a century later, in 1984, over 1200 spinal-cord injured athletes travelled from 75 different countries to compete against other paraplegics and quadriplegics in the world reknown Stoke-Mandeville Games (Taylor et al, 1979, p.457). The first Olympics Games for the Physically DIsabled were held in 1960 in Rome, Italy under Olympic rules, in an Olympic stadium, and attended by 12 nations. It is anticipated that the 1988 Olympics for the Physically Disabled will boast an athlete attendance of over 4,000.

Today's sport organizations, athletes, and administrators are pursuing two ideals. First, to gain full acceptance of disabled athletes in the world of sports competition. Second, to combine disabled sports events with able-bodied competitions at the prestigious and celebrated Olympic Games. The 1984 Los Angeles Olympics witnessed the inclusion of the

1500 meter male and 800 meter female wheelchair races as a demonstration event. This marked the first opportunity for disabled track athletes to win an Olympic gold medal. The demonstration event was an internationally televised public demonstration that "the severely disabled, even those with a disablement of such magnitude as spinal paraplegia, can become sportsmen and women in their own right" (Guttmann, 1976, p.24). The latter goal will involve the future encouragement of race organizers and the International Olympic Games Committee to permit wheelchair athletes and able-bodied athletes to compete alongside each other in athletic events.

Acceptance of disabled athletes by the sporting world, implies a level of acceptance by society at large. The success of the 1984 Olympic demonstration event in influencing the attitudes of society is difficult to measure. However, that the event was held during the Games and at the same site as the able-bodied Olympic events is a step toward full societal acceptance of wheelchair sports and disabled athletes. It is only through the full acceptance and complete integration of disabled individuals into society that the realization of their potentials will be possible.

Over the years, attempts have been made by the disabled to use sport as a means to gain acceptance by society. It has been noted by able-bodied and disabled alike that "sport involvement may make a large difference in the community's acceptance of the disabled" (Ryan, 1981). Although fitness and its apparent gains are a big part of sport and recreational participation, Marty Ball, an international wheelchair athlete, also noted that "the improvements in self-image and confidence", gained through sport competition, "are an important carry-over into everyday life" (Duda, 1985). Just as running offers more to people than mere physiological benefits (Schlenoff, 1980), competitive and recreational wheelchair athletics has been found invaluable, not only for improved physical fitness, but also for increased self-confidence, and fellowship (Stensman, 1985). In Stensman's study (1985), which considered the functions necessary for the achievement of quality of life, mobility-disabled persons ranked 'to participate in sports' as one of the thirty most important functions for quality of life. The therapeutic, recreational and psychosocial skills, gained through participation and competition in wheelchair athletics, are an invaluable contribution to the integration of the disabled into society (Stensman, 1985).

The innovative ideas and constructive projects of Guttmann's followers and today's disabled athletes, serve to increase the public awareness and understanding of the disabled. Just as musicians have recently used their music to carry international messages through 'Bandaid', 'Liveaid', and the like, disabled athletes are using their sports performances to also raise the consciousness of societies around the world. For example, Rick Hansen, a well-known disabled elite international basketball and track athlete, completed a trek around the world in several specially designed wheelchairs. He carries with him a complex message, the ramifications of which will benefit disabled persons everywhere. Soon, the physically challenged will share with society as healthy an outlook upon disability as this young disabled person, who states:

> I've always counted myself lucky that my greatest limitations are physical. To be burdened with a real handicap like loneliness, insecurity, or lack of human dignity might be too much to handle
>
> (Anon, IRUC Pamphlet, n/d).

The development of the positive self-esteem the disabled person gains through sport involvement is reflected in this quotation.

F. Wheelchair Athletes: Sports Injury

Competitive man strives fiercely to achieve the ultimate; to be the fastest, to go the farthest, and to reach the highest possible potential. It is an inherent quality in man, able-bodied or disabled, always to desire more. As an athlete, the body is challenged both physically and mentally to a personal best performance. Along this path toward successful performance in athletics, an athlete must be dedicated to the enjoyment of competition to endure the long arduous hours of training, but is often plagued by sport-related injury.

Injury to athletes of any level is an unwanted disruption in training and competition, which limits or prevents their best performance in sports competitions.

In wheelchair sports, injuries to the shoulders, arms, wrist or hand, carry over to disrupt the ability of locomotion in everyday life. Since their upper body is their power source for locomotion in a wheelchair, or with the aid of crutch(es) cane(s), or braces, the consequences of injured arms or shoulders are devastating to disabled athletes. Although a wheelchair basketball player, for example, could have continued a game with a leg cast on;. a sprained finger or thumb would have hampered not only his ability to shoot a basket, but also his ability to wheel home after the game.

G. Statement of the Problem

There is a very small amount of literature which pertains to the injury types that wheelchair-bound individuals are susceptible to, the potential causes of these injuries, or suggested means for injury prevention. Few of these authors have applied their research to the potential injuries of athletically active wheelchair-bound individuals. Since injury is inherent in sport, and few studies exist which have researched wheelchair athletes, it was appropriate to research the etiology of wheelchair sports injuries. This study's data pertains to the etiology of injuries to wheelchair athletes and forms the groundwork for future research in the sportsmedical aspects of wheelchair athletes and their sports.

The purpose of this study was to provide the physically disabled, their coaches, and the sportsmedicine professionals with information on the etiology of sport-related injuries to wheelchair athletes. The specific objectives of this study were threefold:

1. to determine the nature of common injuries that occur through participation, training, and competition in wheelchair sports and recreation
2. to relate the causes of injury incurred through sport participation of the disabled individual
3. and to describe the current level of participation, training, and competition in

wheelchair sports by Canadian wheelchair athletes.

H. Delimitations

The restrictions placed on the sample and the study are outlined in the following points.

1. Wheelchair athletes involved in the study were registered members of the Canadian Wheelchair Sports Association (CWSA) in 1985.
2. These Canadian disabled athletes were involved in wheelchair sports competition at the provincial level or higher.
3. The competitions these athletes attended were any or all of the following: the 1985 National Disabled Games, the 1985 Canadian Summer Games, the 1985 Windsor Indoor Games, or the 1985 Alberta Disabled Games.
4. All athletes interviewed completed only one questionnaire regardless of the number of Games they competed in throughout 1985.
5. The injuries reported were those that were sustained by all wheelchair athletes in all their months and years of participation, training, and competition in wheelchair sports. This included the time just prior to the completion of the questionnaire.
6. If further injury occurred at events, meets, or in sports participation subsequent to the time the questionnaire was completed, the information in the questionnaire was not updated.

I. Limitations

The certain limitations that became evident as the study progressed are mentioned below.

1. The information gathered was limited by the nature and scope of the survey form used.

2. The categorization by the athlete of the type of injury was assumed to be correct.

3. While the Wheelchair Sportsmedicine Questionnaire was explicitly written, and the questions were clearly stated, the respondents may have misinterpreted some areas. Thus, they may have supplied improper information.

4. Not all injuries were assumed to be accurately reported. The competency, qualifications, and length of time as a competitive wheelchair athlete varied extensively between the athletes. Some athletes may have stated the severity of the injury at a lesser degree, or may have ommitted reporting an injury or injuries. The latter was a special concern for those athletes who had been participating and competing for several years in wheelchair sports.

5. Finally, there may have been errors in the process of collecting, interpreting and summarizing the accummulated data.

J. Explanation of Terms

Abrasion. A scraping away of skin causing redness, local pain, some stiffness, and tenderness: for example, the abrased skin on the inside of the upper arm caused by wheelchair wheel friction.

Blister. Any small sac of clear, saline fluid between the most superficial layers of skin that occurs as a result of friction or a burn. The hands are a common place for blisters in all wheelchair sports.

Body Region Injured. The body locale where the injury or injuries were sustained. The body region most commonly injured in wheelchair basketball was the hand.

Bone Bruise. A superficial discolouration of a bony area with swelling into the tissues from hemorrhaging (ruptured blood vessels).

Bursitis. A bursa is a padlike sac or cavity lined with synovial membrane and containing fluid. It serves to reduce friction between bony structures and muscle, ligament or tendon. An inflammation of this bursa sac is termed bursitis. Wheelchair athletes often suffer from acute elbow bursitis as a direct result of a blow to the elbow joint.

Carpal Tunnel Syndrome. In CTS, the limited space of the carpal tunnel in the wrist is diminished by swelling. This local inflammation puts a substantial amount of pressure on the important median nerve and vessels which pass through the tunnel.

Cause of Injury. An etiological analysis of an injury or injuries which reflects the information given to the athletes by their doctor, physiotherapist, athletic therapist or other medical personnel.

Cerebral Palsy. CP is a group of non-progressive congenital muscular dysfunctions which may result from injury to, or malformation of the areas in the brain which control the body's motor function. The degree of impairment of cerebral palsied individuals ranges from mild to severe. Many CP track athletes use their feet to propel their wheelchairs and so cross the finish line facing backwards.

Classification. A system which analyzes the physical functioning of a disabled athlete (Appendix F).

Concussion. A violent shock or jarring of the brain caused by a direct or indirect blow to the head. The resultant temporary or prolonged impairment of neural and physical functioning is variable.

Disability. The World Health Organization's definition of disability most aptly represents the use of the term in this study. It states that "disability is the loss or reduction of functional ability and activity that is consequent upon impairment".

Dislocation. Total displacement of a joint with loss of articulation of normally opposing joint surfaces caused by a direct or indirect blow. The fingers are most commonly dislocated in sports. An incomplete dislocation is is termed a subluxation.

Fracture. A loss or break in the continuity and integrity of the structure of bone. A broken bone may result from a direct blow, or indirect trauma and is characterized by possible deformity, pain, tenderness, swelling, bleeding, or loss of function. In wheelchair sports, if the lower limb is fractured a cast on the leg would not prevent an athlete from participating or competing.

Incidence of Injury. The frequency of injury occurrence reported as once, weekly, monthly or frequently. Most of the concussions occurred once, whereas blisters and abrasions occurred frequently.

Injury. A damage or hurt suffered through a specific impairment of body structure or function caused by an outside agent of force. In this study all injuries recorded were sustained through wheelchair sport participation or competition.

Laceration. Trauma causing a break in the continuity of the skin characterized by local pain, bleeding, and tenderness. Some lacerations are deep enough to require stitches.

Muscle Bruise or Contusion. Injury to soft tissues caused by a blunt force that does not invade the surface of the skin. Characteristically, a bruise results in local pain, tenderness, hemorrhaging, local discolouration and hematoma formation. Often, discolouration is the only indication of a leg bruise in paraplegics or quadriplegics with altered sensation below the level of the spinal-cord injury.

Nature of Injury. A description of the type of injury sustained. For example, a wrist sprain or a concussion reflects the nature of the injury.

Paraplegic. Any individual with complete or incomplete paralysis of both legs associated with injury or disease to the spinal cord. The characteristic loss of motor function is not accompanied by a sensory loss in polio paraplegics (Appendix F).

Pressure Sore. A sore caused by localized pressure from the body itself when that body part(s) has remained immobile for extended time periods. The most common sites for pressure sores in wheelchair users are over the ischial tuberosities, the lower back where the chair back upholstery is in contact with the body, and the back of the thigh. The denervated areas of the body, especially those with complete sensory loss, are most susceptible to pressure sores. The incidence of pressure sores is increased by inappropriate cushioning, improper wheelchair fit, and wrinkled clothing and is relatively low among athletes.

Quadriplegic. Any individual with complete or incomplete paralysis of all four limbs, commonly associated with spinal-cord injury or disease (Appendix F).

Sprain. A stretching or tearing of the fibers of a ligament as a result of direct trauma to a joint which produces a twisting or movement of the joint beyond its normal range. The wheelchair athlete is free of the common ankle sprain which riddles able-bodied athletics. Yet, a thumb sprain may become a large interference in wheelchair sports.

Strain. A strain differs from a sprain in that it is a stretching or tearing of muscle fibers caused by a violent contraction, excessive intrinsic forces, or over-exertion resulting in trauma to a portion of the musculotendinous unit. A strain is characterized by local pain, spasm, loss of function, tenderness, swelling, hemorrhaging, and strength loss.

Tendinitis. An inflammation of a tendinous structure causing discomfort on both passive and active movements. It is a common overuse condition which occurs frequently to the biceps tendon of the shoulder in wheelchair track athletes.

Tooth Fracture. An obvious deformity or loss of normal structure of a tooth or teeth caused by direct trauma.

Wheelchair Athlete. An individual who must use the wheelchair for mobility in athletic competition. The disabled individual may have a spinal-cord injury, be an amputee, have cerebral palsy, or a motor or neuromuscular impairment. Characteristically, each wheelchair athlete presents with some deficiency in lower limb functioning.

Chapter II

Review of Literature

> We do not succeed in changing things according to our desire, but gradually our desire changes. The situation that we hoped to change because it was intolerable becomes unimportant. We have not managed to surmount the obstacle, as we were absolutely determined to do, but life has taken us round it, led us past it, and then if we turn round to gaze at the remote past, we can barely catch sight of it, so imperceptible has it become
>
> (M.Proust, 1921).

The literature on sports and disabled athletes is limited to reports on sports performance, wheelchair design, sports specific equipment and a few scientific articles. These published articles have analyzed the biomechanics of wheelchair sports, including wheelchair propulsion and the effects of wheelchair design on performance or, have stated the physiological effects of exercise on physically challenged people's position in a wheelchair, activity level, and functional ability related to their disability. Yet none of these studies report the nature, cause, or frequency of sports injuries to wheelchair athletes. Aside from a single survey primarily conducted throughout the United States, and a handful of wheelchair games' medical reports, sports injury occurrence to disabled athletes has not been documented.

The following literature review summarizes those articles written on athlete participation and performance in disabled sports, wheelchair sports history, wheelchair design, equipment modifications, rules, techniques, wheelchair locomotion, and disabled athletes' response to physical activity. The lengthy discussion surrounding the literature review accents the influence of technique, wheelchair design, training programs, warm-up and stretching routines, and the environment on sports injury occurrence to wheelchair athletes.

A. **Sports Performance**

Today's disabled athletes have reached outstanding levels of performance in a variety of sports events (Nilsen et al, 1985). Not only have there been notable improvements in the times raced, and the distances thrown, but the number of skilled disabled athletes has increased. The contributing factors influencing the high performance levels of wheelchair athletes have been the sports specific equipment together with technological advancements in wheelchair design, fitness training, technique specialisation, and the provision of sports organizations and associations.

The involvement and success of disabled athletes has attained regional, provincial, and national recognition. Their phenomenal accomplishments in endurance activities include sub-two hour Boston marathon races (Knaub, USA, 1983, 1:47:10), and sub three-hour Canadian marathon finishes by quadriplegic racers (Mattson, Denmark, 1985, 2:18:50) (Cras 1983; Alexander, 1985, p. 8). According to the literature, wheelchair racing was popularized in 1975 by the first recognized wheelchair racer in the Boston marathon. Bob Hall completed the historic marathon in 2:58:00 (Duda, 1985). As many as 15 of all wheelchair entrants had finished the 1979 Boston marathon course in faster times than the official able-bodied winner, Bill Rogers. Remarkably, four of these 15 wheelies broke the 1979 world able-bodied marathon record of 2:08:34 (Corcoran et al, 1980, p. 697). Later the next year (1980), wheelchair marathoners broke two hours with USA's Curt Brinkman's 1:55:00 finish in the 1980 Boston marathon. This time was soon beaten by Jim Knaub who wheeled the the 1983 Boston marathon course in 1:47:10.

Not only were wheelchair athletes establishing new world records in endurance events, but the previous records in sports events requiring speed or strength were also shattered. Their superior performances in these sports events could be credited to a more concerted effort by disabled athletes and their coaches to prepare for competition both physically, and mentally. Physically, the athletes and coaches had focussed on the importance of sports specific, individualized training programs. The improved level of competition resulted in a greater emphasis on fitness characteristics of strength, endurance, and speed.

Even in the early 1940's, the importance of muscle development and strengthening in wheelchair-bound people was recognized. Strong muscle groups above the lesion in spinal cord injured people were known to be necessary to restore and maintain posture in place of an artificial leather and steel corset (Guttmann and Mehra, 1973, p. 164). Electrical myographical studies on disabled athletes involved in archery, confirmed that archery was an ideal sport for upper body muscular hypertrophy and strengthening of the deltoid, biceps, triceps, trapezius, and rhomboids muscles of the shoulder and upper arm in paraplegics (Guttman and Mehra, 1973, p. 164). Today, many disabled athletes have excelled in the common strength events of weight lifting and field throwing events. Although these sports are perhaps not as visible as wheelchair racing, the performances of wheelchair athletes are creditable (Crews et al, 1982).

In addition to the world record performances in strength and endurance events by disabled athletes, the variation and individual adaptations in technique, together with the technological advances in wheelchair designs led to an increase in efficiency and speed. Today's wheelchair athletes are in prime physical condition, wheel in innovatively designed sport specific wheelchairs, use sophisticated, and modified equipment, and apply an individually adapted, well-practised technique. The skills and expertise of disabled athletes are pronounced in team sports such as basketball. The court skills executed by many international basketball players, serve an indication of the many long hours that these disabled athletes practice. To perform s. l ifficult skills consistently, and with ease, is clear evidence of learned skills. In wheelchair basketball, for example, not only must these athletes learn the skills and techniques of ball-handling and shooting from a seated posture, but they must also adapt themselves to their individual disability-induced limitations. Some of these physical limitations may interfere with accuracy, agility, and balance during sports competition.

a) Disability

In the discussion on both classification and disability in the appendices, it becomes apparent that the physical characteristics of each disabled person are unique. The type of disability, level of complete or incomplete spinal cord injury, amount of denervated muscle, type of muscle tone, and the degree of muscle spasm or flaccidity, all reflect each athlete's physical limitations (Guttmann, 1976; Asayama, 1985; Wolf and Magara, 1976; Corcoran et al, 1980). As in able-bodied athletes these individual physical dimensions are important to athletic success (Byrnes, 1981).

b)Sport Specific Fitness & Skill

Second to athlete individuality in disability characteristics, technique, and skill, the demands of each sporting event for the disabled athlete are uniquely different. Compare for example the physical demands on the athlete in the sports of wheelchair basketball, field events and track. Basketball is largely an anaerobic activity which requires quick bursts of speed, agility, and the skills of dribbling, passing, and shooting; whilst field events demand the athlete have an accurate technique, a high level of concentration, strength, stability and balance. Finally, track and all its diverse events require speed, power and strategy together with excellent manoeuverability around tight corners, and over steep terrain. Each of these sports demands specific skills, techniques, and fitness conditioning which illustrates the importance of sport specific, individualized fitness conditioning programs.

Although these disabled athletes lack total physical functioning of their entire bodies; they compete at world recognized performance levels in many sports events. They have challenged themselves to the full extent of their physical capabilities through comprehensive fitness conditioning programs, practised training techniques, sport specific equipment, innovative wheelchair designs, and intensive, personalized coaching. These physical and mechanical preparations are coupled with mental training. The mental stamina necessary to overcome the anguish associated with the lack of complete physical functioning, and to accept a disability was often cultured through sports involvement. As athletes, disabled people gained the physical advantages of strength, endurance, speed, and benefitted both psychologically and socially. Sports competition amongst others of similar ability, who are all striving for a common goal, created an atmosphere which stimulated the development of integrity, self-respect, dignity, and self-confidence.

B. Sport Participation and the Disabled Person

In 1982, Eisenberg and Falconer estimated that 10,000 disabled males and females participated in wheelchair sports throughout the world (Crews et al, 1982, p. 134). In 1984, the International Games for the Disabled was the second largest sporting event in the world; second only to the 1984 Los Angeles Summer Olympic Games (Mushett in Sherrill, 1984). Perhaps the most visible wheelchair sport is marathon racing (Taylor et al, 1979, p.458; Crews et al, 1982, p.136). Several road races are sanctioned as both able-bodied and disabled events. In some of these races, as many as five percent of racers are wheelchair athletes. By 1982, approximately twenty wheelchair athletes competed in the prestigious annual Boston Marathon. Today, many marathon race orgainizations include a wheelchair division.

Although wheelchair racing is both visible and in "vogue amongst disabled people" many other strength, speed and skilled events have gained recent popularity (Asayama, 1985). Programs for basketball, murderball, volleyball, archery, track and field, racquet sports, swimming, kayaking, and winter sports are expanding to include disabled athletes (Crews et al, 1982, p. 138; Crase, 1987).

In 1949, the first wheelchair basketball tournament included six teams of wheelchair athletes. In 1981, 166 wheelchair basketball teams were playing in 27 sanctioned conferences throughout USA and Canada (NWAA, 1981, p. 2; Byrnes, 1981). Today, able-bodied athletes have become enthusiastic wheelchair basketball players, allowing basketball to become one of the few wheelchair team sports integrated with able-bodied competitors.

The nature of other sports such as the water sports of swimming, canoeing, kayaking and sailing allow disabled persons to participate recreationally or competitively in sports without the use of their wheelchairs. Like the first group of sports, the rules closely resemble the able-bodied sport rules. The canoe, kayak and sailboat are not significantly adapted for the disabled participant. Furthermore, the water provides these athletes with an environment in which thay may learn to overcome many of their unique physical limitations, and strive toward a new independence and criterion for success. Many disabled people discovered that the water medium provided a new independence; a temporary freedom from the locomotive aids used in daily living. Through sheer determination and individual training programs, many of these disabled swimmers have trained to become world calibre athletes. Over the past few decades, the times of these disabled swimmers have improved. The best performance for a quadriplegic class 1A in the 25m breaststroke event was 60.4sec in 1976 (Guttmann, 1976). Later in 1984, the new record for the same event and class was 36.26sec (Pursuit, 1984, p. 3). Today, some of these disabled swimmers are recognized amongst some of Canada's finest able-bodied swimmers.

The third group of sports include many of the winter sports such as hockey and skiing. Certainly a wheelchair would be an inappropriate vehicle of transport for travel over frozen water or snow. To afford the disabled person the challenges of sport participation in these winter sports, vehicles and devices, such as the sledge and ice pick for sledge hockey, and the outriggers, ski sled, and monoski for downhill skiing have been invented (Appendix D). Again, the rules of these winter sports resemble their able-bodied counterparts of ice hockey and nordic skiing and act to encourage equal opportunity and safe participation for all disabled persons regardless of their disability. The skiers for example, compete in different categories determined by their use of equipment, not by their medical disability classification.

The explosive growth of wheelchair sports participation in a variety of sports events during the last decade, is credited to the desire of disabled people to be active, their increased interest in fitness, and the social and psychological ramifications of sports participation (Higgs, 1983, p. 166; Byrnes, 1981, p. 1; Botvin Madorsky and Curtis, 1984, p. 128; Steadward, 1979; Eisenberg and Tierney, 1985; Ryan, 1981). That benefits are derived from participation in sports is both accepted and apparent. Physical activity has long been considered valuable in the maintenance of good health (Stang,1980; Ready, 1984, p. 3; Knuttson, 1973; Nilsson, 1975, p. 210; Zwiren et al, 1975). Guttmann and Michaelis (1970), documented a neurological basis for gains from participation in physical activity by the disabled. They found a reduction in the number of pathological disturbances of the spinal-cord injured person who participated regularly in sports (Byrnes, 1981).

Competitive wheelchair sports have become much more than recreation or therapy (Stang, 1980, p. 5). The benefits of wheelchair sports participation are physical, psychological and social. In the acute phases of spinal cord injury or other disability, early training during hospitalization has been documented to result in faster strength increases accompanied by lessened spasticity (Bishop, 1977, p.372). Owen (1978), stated the rehabilitative goals of increased strength, led to a more active lifestyle. The development and maintenance of upper body strength promoted circulation to vital areas with poor circulation, and demanded a larger fluid intake (Owen, 1978, in Duda, 1985, p.157; Weiss and Beck, 1973, p. 106; Austin, 1972, p. 365). The increased intake of fluids reduced the frequency and severity of kidney infection and kidney stone formation (Jochheim and Strohkendl, 1973, p. 174). All of these important physical benefits convinced those medical specialists involved in the rehabilitative process of disabled athletes to include sports in their treatment protocol. However, the medical profession at large had not counted on the subsequent outstanding sports interest by disabled participants. The role of sports participation by wheelchair athletes had changed from a rehabilitative emphasis to competitive sports involvement (Steadward et al, 1979, p. 119).

In the twentieth century, sports participation has demonstrated that even those who are severely disabled are able to compete as sportsmen and sportswomen in their own right (Ryan, 1981, p. 37; Guttmann, 1976, p. 24). This demonstration of physical prowess by wheelchair athletes encouraged those with similar disabilities to participate in sports, provided role models for youth and disabled spectators, and inspired a greater involvement and awareness of disabled people's capabilities, and accomplishments.

Although competitive sports do not appeal to all disabled people, the performances by today's disabled athletes are verification that "there should be no need to restrain (disabled people) from activity"(Nilsen et.al, 1985 in Byrnes, 1981). However, while in pursuit of their sports goals, disabled athletes may incur sports injuries which range from small lacerations and bruises, to traumatic fractures, concussions and joint injuries. Yet, no studies exist which state, with statistical significance; whether disabled athletes are more at risk to sports injury, the common types of sports injury, the influential factors in sports injury occurrence to this population, or the preferred injury treatment.

Since it is well documented that level of performance, equipment, rules, technique, skills, and level of fitness influence injury occurrence in able-bodied athletes, a literature review of these topics with reference to disabled athletes was included. Furthermore, many well-known principles of sports injury prevention such as hygiene, lifestyle, pre-participation medical examination, training programs, warm-up routines, and rehabilitation are suggested as future recommendations for injury prevention of disabled sports participants.

C. Wheelchairs

There will always be movements and activities which disabled people will not accomplish in the same manner as able-bodied people. The final outcome is often reached, but the method of accomplishment is different; a modified approach often assisted with an adapted piece of equipment. Lacking functional control of their lower limbs, many disabled people have discovered a greater physical independence through: the wheelchair designed specifically for basketball, racquet sports, track, or other sports events; the water medium used in swimming, or other water sports; and the modified equipment used in winter sports.

In wheelchair sports such as track, basketball, rugby and table tennis participation is restricted by the classification system to those athletes who require a wheelchair for locomotion (Appendix F: Classification). Although these athletes must be in a wheelchair in order to compete as wheelchair athletes, they need not be confined to a wheelchair. They may use alternate forms of locomotive aids such as crutches and bracing, a walker, or prosthesis for activities of daily living. In addition to becoming accustomed to their wheelchair, these athletes can optimize the use of a wheelchair by designing their wheelchair to accommodate to both their physical disability characteristics and their sports event(s).

D. History of the Wheelchair

In the beginning, when Guttmann's patients at Stoke-Mandeville, England first participated in wheelchair sports such as archery in 1944 and later basketball in 1950's, the only wheelchair available was the standard hospital wheelchair (Coakley, 1982). This standard hospital wheelchair of the 1940's, and today's specially designed sport wheelchairs are distinctly incongrous both in their appearance and in their performance. For example the type of wheelchair used in athletic competition in the mid 1900's was an accurate predictor of the athlete's placing at the finish line of their track events. Those athletes who raced in the heavier more encumbrant hospital wheelchairs finished behind the athletes who used the lighter sport specific wheelchairs. A description of the traditional hospital wheelchair used for locomotion until the mid 1900's details the stark contrast it made visually to the individually designed sports wheelchairs. The standard hospital wheelchair epitomized the basic qualities of safety, sturdiness, and ease of wheelchair pushing assistance from behind. It weighed approximately 44lbs and was comprised of some 22 parts (Duda, 1985). These parts included the arm and armrest, back upholstery and back upright, axle, brake, footplates, seat rail and upholstery, casters, handrims or handgrips, spokes, tripping levers, tires, wheelbase and large 16"-18" pneumatic wheels. The manufacturers, largely Everest and Jennings Ltd, had adequately met the demands for locomotion of most patients at that time.

As athletics for disabled persons prospered, the inquisitve mind and natural human competitive desire was prevalent amongst the disabled athletes. The safe, heavy, sturdy wheelchair "clunkers" were no longer deemed appropriate to generate the quick bursts of speed inherent in a game of basketball, nor the fast racing times and the efficient manoeuvearability around tight track corners in wheelchair competitions. These competitive wheelchair athletes, compelled to quench their insatiable thirst for success, wanted the winning edge. Thus the birth of the individually designed wheelchairs and their mass production.

E. Wheelchair Design

In the early years of wheelchair athletics, there were only a handful of wheelchair manufacturers. Their product line was limited to one particular wheelchair design referred to in this paper as the standard hospital wheelchair. As the sole wheelchair suppliers, their market was enormous; all the hospitals, rehabilitaion centres, nursing homes and the geriatric population of the general public. A small number of these wheelchairs were used by the few recreationally-inclined disabled athletes. As these athletes became more involved in athletics and more proficient in their sporting events, they wanted a wheelchair that was also more sports specific. Track athletes were perhaps among the first of the disabled athletes to design wheelchairs that incorporated the qualities required to achieve the speed and fast times their aerodynamic sport event demanded. In their backyard garages, some of these wheelchair track competitors-pseudo amateur mechanics were welding aluminum or steels to develop what they hoped would be the hottest, fastest and most closely watched wheelchair at the next wheelchair race. The designs of these 'home-made' track wheelchairs were rated not on their sturdiness, but on the athlete's finish position in each wheelchair track event.

Most everyday and sport wheelchairs shared the same basic characteristics of two larger wheels behind, one or two smaller wheels in front and a seat in the middle. Beyond these very fundamental similarities, the modifications made by commercial manufacturers and private individual designers to the standard hospital wheelchair for specific athletic events, have been dramatic. The major outcome of the modified wheelchair designs were faster, lighter, individually fitting wheelchairs that had a greater ease of handling. These sports wheelchairs differed from everday wheelchairs, according to Gibson (1983), because they were usually built for performance rather than comfort (Gibson, 1983, p.10). The designers were able to optimize the relationships among the seat, the wheelchair frame, and the main wheels to achieve the dual function of adequate comfort for the athlete and efficiency in travel (Brattgaard et al, 1970). The relationship of these independent variables was dependent upon the athlete's body dimensions, weight distribution, muscular strength, balance, available materials and funding. It, therefore, was not remarkable to discover the variation in appearance of wheelchairs at an athletic competition. What began as a personal plight by a handful of enthusiastic competitive wheelchair athletes to reform their hospital wheelchairs to become more efficient vehicles of transport in sports competition, became the twentieth century revolution of lightweight wheelchair manufacturing.

a) Lightweight Wheelchairs

The current state of the art of wheelchair manufacturing is ever-changing. Sport'N Spokes magazine recently conducted a survey of sport wheelchair or lightweight wheelchair manufacturers (Crase, Robbins, Schmid, 1987). According to their 1987 statistics, there are more than 83 models of wheelchairs marketed by 22 different manufacturers in Canada, USA, and internationally (Crase et al, 1987, p. 18) The major manufacturers; Everest and Jennings, Quickie, and Quadra (by Motion Designs) produced more than one kind of wheelchair often according to the demands of different sports events, and to accommodate the particular wishes of each wheelchair athlete. The wide range of models were designed for everyday use, track racing, children, and specific sports. In addition, within each of the design lines, the chairs could be custom fit. Many retired and some active athletes designed and molded custom chairs for their own private enterprises or on contract with some of the large manufacturing firms.

The materials used in the manufacturing of these lightweight wheelchair frames included aluminum, stainless steel, Kevlar-Epoxy, 4130-chromoly or aircraft tubing. The wheelchair seats were often padded and covered with nylon, sailcloth, and even gortex. The general characteristics of the 83 models varied in price from US$500 to US$2500, weight from 9.5lbs to 20lbs, construction, foldability, and appearance (Crase et al, 1987). However, all the models shared the basic qualities of relative lightness, manoeuveurability and adjustability.

The main theme of lightweight wheelchair construction was to design wheelchairs that "fit the user; the user doesn't fit the chair" (Crase, May/June,1987). For example, one of the manufacturers models' has customizing features which include 9 frame widths, 3 back height ranges, several seat sling depths and 10 standard frame colours. These options allowed their design to meet a variety of individual needs and lifestyles. Each of the 22 manufacturers had a unique characteristic of their design ranging from a pushbutton folding mechanism to an oval handrim or even a kingpin automotive steering system (Crase et al, 1987). This unique characteristic becomes the selling point of the manufacturers and their distributors in the twentieth century, highly competitive world of lightweight wheelchair manufacturers.

b) Individually Designed Wheelchairs

In most able-bodied sports, perhaps with the exception of handmade kayaks, few elite athletes construct their own sports equipment. However, in several disabled sports, especially wheelchair track, many athletes not only create new designs for their chairs but also construct their wheelchairs themselves. It was some of these designers, the wheelchair athletes themselves, who soon became consultants to the presently founded manufacturers who were looking to expand their product line. Meanwhile other wheelchair athletes began marketing their design themselves to friends and fellow competitors in their own country and abroad.

It was not surprising that the 1983 Sport'N Spokes survey of lightweight wheelchairs accounted for 13 wheelchair manufacturers (Crase, 1983, p.22). Less than five years later in 1987 there were 22 manufacturers who marketed their products throughout the world via authorized dealers. Many of these manufacturers provided warranty on their chairs, a toll-free phone number, and direct delivery to a foreign country. This abundance of manufacturers and their wheelchair designs was certainly a far cry from the sole design of the standard wheelchair used in early wheelchair sports competitions in Guttmann's era.

F. Sport Specific Wheelchairs

In only two decades, the design of the standard hospital wheelchair had been altered dramatically. The modifications of the hospital wheelchair in appearance, material construction and function transformed the passionately termed 'clunker' wheelchair into today's many designs of sport wheelchairs. Many of the alterations in sport specific design such as seat height, camber, rear wheel placement and wheel size were made to accommodate the elite athlete's higher aspirations of greatest speed, agility and manoeuveurability, their physical characteristics, and their skill level and technique.

The specificity of a wheelchair to a disabled athlete is as important as a pair of track shoes to a track athlete, (except Zola Budd) or a bicycle to a cyclist. Just as running, jogging, and cycling are a primary form of endurance activity for many able-bodied athletes, wheeling is its disabled counterpart. The wheelchair, track shoes, and bicycle all perform necessary functions toward the achievement of the goals and objectives of all athletes both able-bodied and disabled. In essence, these inanimate objects are an extension of the athlete. To this end they are tailored to meet the specific requirements of speed, lightness, and other qualities specific to each event. Not only are there athletes who use specifically designed track wheelchairs for track sprints, middle distance, and road races, but many other athletes use a track chair and wheeling as their primary means of endurance training. Thus each athlete may compete in more than one wheelchair. They may own a wheelchair for basketball which they use for basketball games and skill training, but they may also own a track chair for sprint work or aerobic wheeling. The basketball player's wheelchair would be built to endure the game's forceful hitting, and yet be light enough to allow quick stopping and starting for short bursts of speed. Therefore the basketball wheelchair had to be both sturdy and easily manoeuvred, while the track wheelchair was lighter and less durable.

Furthermore, in addition to the demands of the sport, the physical characteristics of each disability influenced the ultimate wheelchair design. Although the sport of wheelchair rugby requires similar qualities as basketball, the players in wheelchair rugby have less balance, power, and upper body strength than wheelchair basketball players. This is due to the higher level of spinal cord injury of the quadriplegics who played wheelchair rugby. These athletes characteristically moved more slowly on the court, had less agility, and less balance in collisions, and on short stops and starts. Even within one sport, the disabilities of the athletes varied. In basketball, or tennis, some high-level single or double lower limb amputees often required additions to their wheelchairs, such as tipping levers, to compensate for their great tendency to tip backwards.

A third variable which influenced design was the skill level and technique of the athlete. The wheelchair athlete who competed successfully in field events, relied heavily on their refined throwing techniques. Their chair was required to provide lots of stability, and to have removable backs and sidearms to allow the athlete to re-position themselves in their wheelchair for maximum throwing distance. The sport specific wheelchair design and ensuing manufacturing revolution was born out of the wheelchair athletes' desire toward success at an ever increasing level of competition, and diversification of sports and their events.

In time there emerged four major categories of wheelchair models/designs for: 1)basketball, tennis and everyday; 2)track; 3)juniors and children; and 4)geriatrics (Crase et al, 1987, p. 17). There was a great variety of design within each of these model categories. Supposing a comparison were to be made between the disabled athletes' variety of wheelchair design models, and able-bodied athletes' footwear or equipment. The relationship of a wheelchair to a disabled athlete would be deemed as important as the chosen footwear or vehicle to an able-bodied athlete. There are, at best, hundreds of models and design of footwear specifically designed to accommodate the qualities and demands of the world of able-bodied sports. For example, hiking boots, downhill ski boots and skis, track spikes, aerobic shoes, wrestling boots, gymnastic socks, hockey skates and basketball hi-top court shoes, to name only a few. Similarly, wheelchairs and sports equipment used by disabled athletes in sit-skiing, track sprints, marathons, basketball, sledge hockey and wheelchair rugby are vastly different. Perhaps in the near future, wheelchair sports will advance to new heights of equipment specification. The wheelchair basketball team will perhaps have different wheelchair designs and products according to the different positions on the court. These specifications would be similar to the adaptations made to the protective equipment for different positions in for example, able-bodied football or for able-bodied hockey goalies.

Each athlete must combine the qualities of strength, skill, speed and power to achieve excellence in sport. For example speed is important to track sprinters, while strength is most important to powerlifters. Thus, just as track sprinters must train themselves to be the fastest, the sprinters' wheelchairs must be designed to travel at great speeds. As a result of this relationship of sports qualities, sports wheelchairs vary in design as much as the sports events they are used in.

(i) Track & Road Racing Wheelchairs

The track athlete became the most demanding of all athletes towards their wheelchair design. Not only did the wheelchair type vary according to the different track events, but the size and type of the wheels, tires, and handrims varied within the chair used for a specific event. To be an elite able-bodied track athlete, one requires only a pair of track shoes, fitness, and a little time. The terrain and grade can be variable, uphill, gravel, mud, cement, cobblestone, a farmer's field, snow, or a sandy beach. The type of shoes worn varies according to the terrain, the speed, and distance of the run. Conversely, the track wheelchair athletes do not have as great a variety in terrain upon which they are able to manoeuver their chairs in races or training. They are restricted to wheeling over a relatively level terrain clear of rocks, snow or mud, using a wheelchair that has been tailored to suit their individual needs. Just as the able-bodied athlete varies the use and length of the spikes on the track shoe, the wheelchair athlete tailors a chair to suit both the demands of their sporting event, the terrain, and their individual disability.

In the initial stages of track wheelchair design, there was a great deal of trial and error involved in materialization of the designers innovative ideas. If the chair was aerodynamic and light enough for a fast sprint, then it probably would not have enough manoeuveurability or stability for the athlete to engineer around track corners at high speeds on all wheels. In the longer road races of 5-15km and marathons, the terrain both uphill and downhill, the uneven surface and the high speeds travelled, meant further negotiation on wheelchair design. In road races, the athlete's track wheelchair had to be durable for the speeds gained travelling downhill and over uneven surfaces, and be light enough for the uphill climbs. Yet, like in all track events, the road racing wheelchair had to be aerodynamically constructed to obtain the fastest overall race times.

Some of the differences in the construction and appearance of the track wheelchair used for sprints and a chair designed for road work and road races were the variance in handrim size, wheel size (especially rear wheel size), and in the provision of braking and steering mechanisms. It was the well-seasoned road racers who, encouraged by their occasional spills while travelling at break-neck speeds, designed a braking mechanism and an accurate steering device. These road racers often travelled on hilly marathon and road race courses at speeds which have been clocked in excess of 55kph (Vince, Ierretti, 1986). In the ensuing experimentation with various mechanisms to provide greater control at these high speeds a number of innovative steering devices were designed. It is now an updated adjunct to the ISMGF rules of track chairs to allow steering devices in road races including marathons.

A track racing chair is similar in construction to a racing bicycle with its expensive tubular tires, high quality bearings and lightweight frame (Rudwick, 1979, p.10). A sport wheelchair used primarily for marathons and road racing features rear wheels that are 27" opposed to the standard size, and handrims that are from 11"-13"in diameter and are attached to the spokes via clips. The front caster(s) characteristically found on the road racer's chair were up to 12" in diameter and often were equipped with steering handles for directional control. The large wheels exhibited camber which meant that the bottoms of the wheels were farther apart than the top, or more simply stated, the large wheels were not parallel (Rudwick, 1979, p.10). Recently, track wheelchairs sport a single caster wheel. The resultant three-wheeled vehicle has proven to have greater maneouveurability in tight track corners, and maintain the intended line of travel downhill more successfully (Viger and Kostelyk, 1988).

(ii) Racquet Sports Chairs

The design for tennis wheelchairs is similar to the design of racquetball, basketball, baseball and rugby wheelchairs. These sports all require a wheelchair that has speed, agility and sturdiness. The rigours of these sports demand that the wheelchairs be capable of withholding their shape and structure upon contact with other chairs, the floor or surrounding walls. These wheelchairs generally are equipped with standard size or 24" wheels, small front caster wheel(s), anti-tip devices front and rear, and standard size or 13" handrims.

(iii) Junior Chairs

The wheelchair designed specifically for the child or youth is similar to all other designs of sport specific wheelchairs. The expense of purchasing a wheelchair for each sport is not as common for this group of young disabled athletes. However exceptions are often made in the purchase of specially tailored chairs for track sprinters. Once a member of a sport group or club, the child may be able to acquire a wheelchair frame that is then adapted to fit their physical dimensions. Thus the smaller size is the main difference in the appearance and construction of the junior wheelchairs. These wheelchairs are basically miniature replicas of the adult size wheelchair models. Many of today's wheelchair manufacturers market a separate line of child and youth wheelchairs.

G. Equipment Modification

The focus of sports for the disabled had changed from participation by the disabled on the grounds of the Stoke-Mandeville hospital in the 1940's, to the sweaty training bouts and hard fought battles in wheelchair sport competitons in the late 1900's. There were many athletes who enhanced their capabilities in sports events, especially their balance, by the qualities of their sporting equipment. For example, their particular wheelchair design may have increased their sitting trunk stability and balance. Thus, sitting in their wheelchairs for sports competition provided their bodies with a biomechanical advantage for wheelchair sports techniques. For example, a class III spinal cord injured athlete (T6-T9) has no useful lower abdominals, and therefore experiences difficulty with balance. Perhaps the design of this track athlete's wheelchair included a bucket seat which positioned the upper body in a stable upright posture. Seated in the track wheelchair, the new body posture eliminated the need for abdominal support. Thus the wheelchair design alone created an advantage over another class III athlete who competed in a different wheelchair design which may have required abdominal musculature for balance and optimal body positioning. The drastic equipment design and material modifications caused two divisions in athletic performances. First, the alterations in sporting equipment had effectively eliminated some of the differences between classes. Thus, when competing in their innovatively designed track wheelchairs for example, these athletes were considered less disabled than their medical classification. Thus split classifications were developed which allowed athletes to be functionally classified into different classes for different sports events. In this study, there were 10 athletes who were split classified. For instance, a spinal cord injured athlete may have competed with class II field competitors and class III athletes in track events.

Second, although the material and design modifications to wheelchairs had proliferated most nations, the resources were not accessible to all athletes. In 1982 at the Pan Am Wheelchair Games in Halifax the Jamaican teams still attempted to race in their "clunkers" or standard hospital wheelchairs. These chairs, it was agreed, were a factor which influenced their slow, last place finishes despite their enthusiasm. Lessons were learnt on the competition fields and race tracks, and in the following Games standard hospital wheelchairs were not sighted amongst the athlete competitiors.

Inretrospect, the tremendous variety of equipment and footwear designs found in the able-bodied sporting world is mirrored in the variety of sport specific equipment and wheelchair models for disabled athletes. The numerous sports equipment manufacturers marketed many wheelchair models which each had several designs. Within each design there [illegible] the option of customization not only for body size but also for colour and material construction. The wheelchair alterations included different sized handrims, and wheels, and different relationships in the seat angle, axle placement, and wheel placement (camber). Additions of equipment such as winterized tires with traction studs and/or chains are often not well justified as they added bulk, and weight, and resulted in a decreased maximal speed. Although Rick Hansen had the opportunity to use this type of wheelchair in his Man in Motion Tour, most sport competitions today use indoor facilities or delay competitions when inclement weather interrupts a practice or race.

Sports Equipment

Only the greatest of imaginations will capture what the future holds for wheelchair sports equipment modifications. The dreams and innovations in wheelchair designs and sports equipment of today's disabled athletes may become tomorrow's reality. However, if the equipment and sports modifications are to be effective in increasing athletic performance, encouraging mass participation of disabled persons in sports, and minimizing the effects of the terrain, climate, and the athletes' disability, then they must idealize the goals, objectives and criterion of the disabled athlete and their sport.

Many water sports require few specialized pieces of sports equipment. Although some classes of disabled athletes use floatation devices, most wear only swim suits and swim goggles. Boating and other aquatic sports require that the sports participants wear specific preventitive equipment such as lifejackets, helmets, and even gloves. The equipment guidelines for these able-bodied sports seldom require exceptions for disabled athletes' participation.

The winter sports of sledge skiing, mono-skiing, outrigger skiing, and sledge hockey are only a few of the popular snow and ice activities. The thrill of winter sports participation has been exhilerating, challenging, and immensely popular. The innovatively modified equipment used by disabled participants is individually fitted to each athletes level of functional ability and skill. The skill determines the type of assistive device or equipment necessary for the disabled skier to participate and compete in their sports event. The equipment used included outrigger poles which were used most often by amputee skiers, or cerebral palsied skiers. Both these disability groups lacked appropriate balance. The additional hand-held skis improved their balance by the provision of a greater base of support on the snow. Mono-skis are commonly used by high amputees and spinal cord injured athletes. They enclose the body and allow the athlete to guide the direction of travel of the single ski using hand held ski poles. High spinal cord lesioned athletes often chose a ski sledge. The sledge is similar to the bobsleigh, with the inclusion of a high neck roll bar. Like outrigger skiers, sledge skiers use their arms for directional control and balance. However, unlike the outriggers, sledge skiers use shortened ski poles rather than mini skis (Appendix E).

Other winter sports participants were involved in sledge hockey, ice-picking, and cross country sledging. A modified wooden sleigh with blades was used by both sledge hockey players and ice-pickers, while the blades were replaced by runners for cross country sledgers. The sledge hockey players used a long pole for propulsion. One tip of the pole was prepared with an ice pick while the other end had a rubber stopper. The former end was used for propulsion on the ice, whilst the latter end was used to shoot the puck into the goal (Appendix E). In both cross country sledging and ice-picking, two modified ski poles were used. Sledgers shortened the ski pole's length, and ice pickers adapted one end of the shortened ski pole with an ice pick for traction. The appropriate protective equipment for winter sports participation included warm clothing, gloves, a helmet, and elbow pads.

H. Rules

The rule books of all sports are constantly being rewritten for many able-bodied and disabled athletes. Rules are influenced not only by the desire to provide a safe environment for sports participation and competition, but also to provide equality in competition for all athletes. Therefore, to ensure equality, rules must be incorpated that deal with guidelines for: sports event objectives; sports equipment both protective and sport specific design, technique, competitors, and the playing surface.

The rules and objectives of many able-bodied sports such as basketball, archery, track and field, and racquet sports are only slightly varied to allow disabled participation. Disabled athletes use a basket of the same height in basketball, race the same distances in track events, and compete using the same equipment for racquet sports as able-bodied athletes. However disabled athletes participate in their sports specific, individually designed wheelchairs and compete against athletes of similar disability classification. The enforcement of appropriate guidelines both for wheelchair design and for sports competitors' classification are the two most complicated and frequently altered areas of wheelchair sports rulings.

In Canada, there are two sports governing bodies which regulate suitable and acceptable rules for wheelchair sports competition: ISMGF, International Stoke-Mandeville

Games Federation, and ISOD, International Sport Organizations for the Disabled. The official rules set by each association are different, but rulings controlling certain aspects of the functional wheelchair components and sports specific equipment are agreed upon by both bodies. In wheelchair sports, these rulings restrict the size of the drive wheels, the absence of gears, levers, or chains, the number of push rims, and how the legs may be secured while the athlete is competing in the chair (NWAA in Murphy, 1986, p.55). Specifically, wheelchair track competitors;

> may use only their hands to propel the chair, and feet must remain on the foot rest at all times unless the individual has a doctor's certificate indicating this is not possible. The deciding factor at the finish of all track events is the leading wheels of the competitor's chair.
>
> (OWSA Handbook, 1982)

This track ruling is enforced amongst all wheelchair track athletes including cerebral palsied athletes. Higher classes of cerebral palsy athletes may compete with their wheelchairs facing backwards. The finishing position for these athletes, who use their feet for propulsion, is decided by the leading wheels which would be the larger front wheels. In water sports the use of a floatation device, and class-restricted race events are outlined in the rulings. In field events, rules and regulations monitor the positioning of the athletes and their wheelchairs within the throwing boundary, the size of the throwing surface, and the method of distance measurements for each throw. In winter sports, many rulings pertain to the technique followed according to race objectives, and the appropriate protective equipment, acceptable techniques, and race or game objectives. The great variety of sports equipment for winter sports, and the significantly different wheelchairs used in track, road racing, and basketball are an illustration of how technologically advanced sports equipment, wheelchair designs, and innovative techniques have influenced the guidelines and rules of disabled sports.

I. Technique

Success in sports performance is achieved through man's inherent desire to achieve the Olympic ideals adopted from the latin phrase: citius, fortius, altius (faster, stronger, higher). To reach these ideals in each sports event, athletes rely upon interrelated and dependent variables such as specifically designed sports equipment, an efficient technique, technically sound coaching, and appropriate physical training. In track events, field events, water sports and winter sports, disabled athletes maximize their performance by modifying their sports equipment and adapting their wheelchairs to suit the terrain, their disability, and to minimize the stress, fatigue, and high energy expenditure of wheelchair sports. The modifications and adaptations to wheelchairs and sports equipment are a reflection of the techniques used by athletes in their sports events.

J. Wheelchair Propulsion

In addition to track athletes, many athletes wheel even if it is not required for competition in their sports event. Athletes who compete in water sports, field events, and winter sports wheel in everyday activities and for aerobic training. The various techniques of wheelchair propulsion are a reflection of disability, wheelchair design, skill, and experience. Although unestablished, it is likely that a relationship exists between the number of years of wheelchair use and the recency of disability. Perhaps the relative ease of wheelchair handling improves with time. Those athletes who train and compete in a wheelchair, but use alternative devices or aids such as canes, braces, or crutches, spend less time in a wheelchair. The greater amount of wheelchair use in activities of daily living, the greater the number of years as a disabled person, and the greater the number of years in each sport as a competitor or participant are all factors which promote ease of wheelchair mobility (Brasile, 1986, pp.6-13). Therefore for those persons whose disability dictates daily wheelchair use, the wheelchair becomes an accepted extension of themselves. Secondary to experience, a biomechanically efficient style or technique of wheelchair propulsion can be learned. Through knowledgeable coaches and regular practise, athletes strive to optimize their stroking or pushing technique to suit their wheelchair, physique, fitness level, and sports event(s).

Recently, researchers have studied the efficiency of wheelchair propulsion variations apparent in wheelchair racing techniques. Technique variations have been established based upon body position in the wheelchair, arm length, hand grip, hand/wrist pathway, and pushing frequency (Byrnes, 1983 in Alexander, 1985; Glaser, 1980; Glaser et al, 1979; Walsh, 1987; Steadward, 1979; Spooren, 1981; Higgs, 1983). Higgs (1983), a Canadian biomechanist studied the wheelchair characteristics of 49 successful track athletes at the 1980 Holland Disabled Olympics. He found that sprint athletes' wheelchairs had significantly shorter and wider frames. The seat placement in sprinters' wheelchairs was forward and higher than middle distance wheelchair track chairs. Anotherwords, although the wheelchair design chosen may have been well suited to the athlete's physical characteristics, and wheelchair stroke technique, it was further modified to suit their sports event.

In 1979, Steadward examined the phases of the conventional wheelchair racing technique. He concluded that there should be no pause between the two identified phases of the stroke: drive phase and recovery phase. To achieve the idealized circular path of recovery along the arc of the wheels and to maintain a streamlined body position, athletes modified their wheelchairs. The larger drive wheels were cambered and the size of the push rims were altered to allow a complete hand grip on the push rims. Asayama et al (1985) correlated push rim sizes and arm work. He stated that, although influenced by the terrain, there is a positive relationship between small push rims and arm muscle contraction. The arm muscles contracted over a relatively long duration and recovered between each contraction for a longer duration than with the larger push rims.

Spooren (1981) emphasized the importance of a downward pushing angle in the drive phase and a zero recovery phase. No other researcher has advocated a wheeling technique that was characterized by no recovery phase. Byrnes (1983) acknowledged the presence of different pushing styles but it was not until 1983 that hand/wrist pathways of wheelchair propulsion were studied. Higgs (1983) identified three distinct hand/wrist pathways used by Olympic wheelchair track athletes. Although unable to state the influence of hand path variations on performance, Higgs recorded these pathways as a near perfect circle, a figure eight and the common eliptical pattern. The efficiency of the chosen wheelchair propulsive stroke was dependent upon the maximal force applied to the push rims over variable terrain with the minimum of stress, fatigue, and energy expenditure. Byrnes (1983) stated that experience alone resulted in maximal force application by elite wheelchair athletes. Their well-practised technique, together with a short recovery path he stated, would optimize the force application. In his study of 10 wheelchair athletes, Byrnes (1983) noted the importance of a shorter recovery phase rather than a smaller sized push rim.

Recently, Walsh (1987) investigated the influence of pushing frequency on wheelchair sprinting speeds. Maximal force application in sprinting she advocated, was achieved by a short drive phase; "fast pushing frequency and short pushing length" (Walsh, 1987, p. 13). This was the first published study which investigated the importance and influence of frequency rather than wheelchair stroke length. She advocated a short drive phase; "fast pushing frequency and short pushing length" to achieve maximum sprinting velocity (Walsh, 1987, p. 13). This was the first published study which investigated the importance and influence of frequency rather than length of the wheelchair stroke.

The force implied to the push rims is partially determined by the hand grip on the push rims. Few articles have discussed the similarities of hand grips. However, a visual study of the wear patterns of gloves worn by wheelchair athletes suggests that hand grips are similar. Except for the backhanded technique used by quadriplegics, the greatest amount of force is imparted through the thumb and index fingers of many wheelchair track athletes (Plate IV.1).

In 1985, Ingmar of Sweden introduced a revolutionary hand grip for fellow quadriplegic racers. Using the dorsal aspect of the hand and wrist together with an oversized, reinforced glove, Ingmar effectively decreased the energy cost of wheeling for quadriplegics.

This backhanded technique effectively propelled the wheelchair by contacting the push rims with the back of the hand, drawing the hand up and over the push rim, and finishing the powerful stroke with lower arm supination (Alexander, 1985, p.2). This technique demanded movement from the available functional muscles of the quadriplegics' shoulders, supinators, and wrist extensors. The marathon records for this quadriplegic class of track athletes were shattered by more than one hour in 1985. This dramatic performance improvement was linked to the efficiency of Ingmar's backhanded pushing technique. The grip quickly gained popularity amongst quadriplegic track competitors throughout the world.

The high visibility of wheelchair track has been an encouragement to the handful of researchers who have studied technique efficiency of wheelchair track athletes. Now that technical articles are available in this sport, investigators should focus their research on sports specific technique characteristics, of other less visible, or less developed wheelchair sports.

K. Wheelchair Locomotion

The important variables of wheelchair design, sports equipment, and technique have influenced the efficiency of wheelchair propulsion only marginally. Physiologically, a high correlation between asynchronous arm movement and energy consumption has been found (Glaser et al, 1980). Few people realize the physical stress, fatigue and high energy cost associated with wheelchair propulsion. The asynchronous upper limb movement of wheelchair propulsion has been identified as the source of high energy consumption. The 'unnatural motion' of manual wheelchair propulsion is energy wasteful (Glaser et al, 1980, p. 506). For a novice, just minutes propelling a wheelchair produces blisters, and aching thumbs, fingers, and shoulders, a fact which painfully confirms that "the arm muscles were simply not made for locomotion"(Glaser et al,1980). Glaser (1980, 1981) an American physiologist who has specialized in physiological testing of wheelchair athletes, studied able-bodied subjects and different forms of locomotion (Glaser et al, 1980, p. 506). He concluded that walking and bicycling were among the most efficient modes of locomotion. "Think of how you walk or ride a bicycle", Glaser explains, "You use an alternating motion" (Glaser, 1981). The alternating motion used to walk or to ride a bicycle was physiologically a less strenous movement (Glaser 1980). Both walking and cycling are dissimilar from wheeling. First, walking and cycling employ asynchronous or reciprocal limb movements which the nervous system coordinates better than simultaneous movements (Higgs, 1983). Second, the wheelchair user must rely upon the upper body musculature for movement. Thus, in addition to the demands of the synchronicity of wheelchair propulsion, the wheelchair user is at a greater and more immediate disadvantage because the physiological response to arm work is mechanically less efficient than leg exercise (Asayama et al, 1985; Stewart, 1983; Ready, 1984). In accordance with Asayama et al's work (1985), many scientists are in aggreement that the VO2 maximum of arm work is 35 percent lower than that of similar leg exercises (Grimby, 1980, p.14; Astrand and Rodahl, 1970, p. 168). Also, Sheehan (1986) has observed that the maximum heart rate is generally lower for athletes who exercise in a sitting position (Sheenan, 1986, p. 69; Duda, 1986, p. 56).

The more physiologically demanding asynchronous limb movement, the smaller musculature, and the decreased maximum VO2 of the upper body as compared to the lower body, are all factors which lead to the high energy cost of wheelchair propulsion. A further reduction of the physical work capacity of the arms is directly related to the population who use wheelchairs. The disability types, including paralysis, are associated with altered bodily functioning, balance, denervated musculature, muscle spasm, or flaccidity. All wheelchair users given their limited physical work capacity, are required to use relatively weak upper-body musculature to propel themselves in their wheelchairs.

Unfortunately, wheelchair athletes also must deal with terrain variations. Few sports events are conducted on the level, uniform surface of a basketball court. Track athletes, for example, contend with tight track corners, while road racers contend with architectural, and topographical barriers which include sidewalks, curbs, potholes, and hills. According to both Long (1984) and Voigt and Bahn (1969) wheeling uphill caused rapid localized muscular fatigue (Long; 1984, p.140). Marshall (1984) similarly described the hardships faced by downhill wheelchair propulsion. He recognized that the variation in drive wheel camber is the single worst mechanical problem wheelchair users contend with on downhill courses. While the smaller front caster wheel(s) follow the steepest downhill line, the desired course may not be along this line of travel. Thus athletes must continually correct their wheelchair's direction of travel by altering the drive wheels (Marshall, 1984, p. 303).

It is out of these 'hardships' that several types of steering and breaking mechanisms have been invented. Although many of these mechanisms are presently dissallowed, rulings may change if the mechanisms increase the safety of road racing. The wheelchair designed with a single front caster and a steering mechanism has been a successful and popular combination among middle distance and road racers.

In addition to the difficulties associated with wheelchair travel, both uphill and downhill, Marshall (1984) noted that the shoulders of roads affected wheelchair propulsion. Due to the inherent convex contour of roads, there is a continual drag toward the ditch or gutter when wheeling on the road. Ideally, wheelchair users would prefer to propel themselves along the crown of the road, as the 'ditchward drag' results in an increased strain to the outside or ditchward arm. However, traffic on busy roadways prevents this choice except on roadways which have been closed for road race competitions.

Coupled with a variable terrain, is the climatic effect on the terrain surface. The racing surface could be slick, slow, bumpy, or soft as determined by rain, ice, snow, debris, or mud. The variable climatic conditions of race courses not only increase the hazards associated with sports participation, but also alter the energy consumed.

Finally, there are those factors which involve the physical parameters of wheelchair locomotion. These factors include not only the physical characteristics of the wheelchair such as the handrim size, camber, weight; and the environmental elements such as grade of slope, and terrain; but also the individual's present physical cardiovascular fitness and strength (Hildebrandt et al, 1970; Voigt and Bahn, 1969; Zwiren and Bar-Or, 1975).

L. Fitness and Training in the Disabled Athlete

As wheelchair designs became more sophisticated and the techniques of wheelchair athletes became more refined, a good wheelchair no longer determined the champion of the sports competition. Instant success could no lon[illegible] be achieved merely by adaptations of the standard hospital wheelchair. There became more to winning than simply a wheelchair that weighed less than 40lbs. Those athletes who had access to local recreational or competitive community facilities were beginning to train before the day of the competition. Many were coached on sports specific techniques, had constructed or acquired sports specific wheelchairs, and had diligently adhered to rigorous training schedules. "It used to be that I would compete in 5 or 6 events, some of them I had never even tried before" (Ell, 1985) Today, inexperienced athletes who compete in sports events would have difficulty placing in their heat. If unfit, they certainly would be unlikely candidates for medals. In track events untrained, poorly equipped competitors were sure to be quickly overtaken by the more fit athletes.

(i) Cardiovascular Fitness

The physical stature of athletic competitors, their cardiovascular fitness and strength, are vitally important characteristics (Hildebrandt et al, 1970; Voigt and Bahn, 1968). The importance of fitness training specific to disabled sports involvement is supported by medical and health professionals (Jackson, 1985; Ryan, 1981; Ward, 1982; Steadward, 1979; Walsh, 1987). Not only must athletes use sports specific sophisticated equipment, be coached well, and be skillful in their sports events, but the physical demands on their energy expenditure must be met conservatively.

To allow for exercise-induced lactic acid and other waste products to be removed from working muscles, and energy to be replaced, fitness training programs must be complete, safe, and personalized. Although wheelchair athletes rely on anaerobic power for many sports (Corcoran et al, 1980, p.698), anaerobic training must be accompanied by preseason aerobic endurance-conditioning programs. A high level of aerobic fitness increases the body's ability to remove waste and replenish energy.

All kinds of physical work, including sports activities, demand that the working muscles be continously supplied with sufficiently oxygenated blood by the cardiovascular system. In some severe physical disabilities, the muscles which assist the heart and lungs, such as the thoracal intercostal muscles, may be either partially or completely denervated. Their diminished or lack of contractility depresses the functional capacity of the cardiovascular system. In some instances, the extent of the paralysis may inhibit the parasympathetic and sympathetic nervous systems full functioning capacity (Grimby, 1980). Furthermore, the physical characteristics of quadriplegics or more severely disabled spinal cord injured people often include a low heart rate which does not rise with exercise (Glaser, 1978, p. 341; Grimby, 1980)(Appendix H). In light of the physical complications and restrictions associated with wheelchair athletes' disabilities, a knowledgeable coach is required to prescribe individualized, sports specific training programs for competitive wheelchair athletes. Yet, "training" states Ward (1982), a well known Canadian track and field and swimming coach, "should not be treated as therapeutic exercise, but physical training for the competitive athlete" (Ward, 1982). At a competitive level, few programs exist that have been designed specifically for the training of the wheelchair athlete (Nilsson, 1975; Knuttson, 1973; Ekblom and Lundberg, 1968). Yet, a glance at the more than 35 different sports including racquetball, basketball, skiing, swimming and road racing, leads to the conclusion that, "a high degree of training is necessary" (Crews,1982). Wheelchair marathoners, for example, must not only have the fitness level to maintain their remarkable race pace, but the mental training to complete this gruelling endurance event. Their training must prepare these athletes to adapt to all types of terrain and climate. Some elite 'wheelies' have competed in two marathons, one week apart, and have ranked amongst the top five competitors for their age category in both races (Ierretti and Vince, 1986). Although some medical physiologists and specialists may debate the health hazards of this feat, their physical fitness capacity is indisputable.

M. Related Review of Litera

Whether the changes that occur within sports begin with the athlete's technique, or futuristic engineering developments in equipment design and materials; these changes all influence the ultimate performance of the athletes, sports rules, and the nature and cause of sports injuries. Unfortunately, the leaps and bounds in wheelchair sports participation, performance, and equipment design have not been accompanied by an increase in available sports medical information on the disabled. The field of sports medicine has received a considerable amount of attention over the past few decades. The numerous medical journals, books, and articles which have been published in recent years on injury treatment and prevention are evidence of the popularity and publicity afforded able-bodied athletes and their injuries. Yet, sportsmedicine also has an important role to play in the present and future endeavours of disabled athletes. The ongoing involvement of physicians, trainers, and other sportsmedical team members is crucial.

Their involvement in wheelchair sportsmedicine is essential in order that professional awareness of available athletic activities for the disabled athletes is increased, the athletes are examined and classified, and assistance is provided in the prevention, recognition, diagnosis, and proper treatment of wheelchair athletic injuries. In conjunction with the Stoke Mandeville Games, a small group of doctors with a vested interest in spinal cord-injured athletes, held annual meetings. On July 28, 1961 these medical doctors united to encourage the advancement of medical knowledge regarding disabled athletes by founding the International Medical Society of Paraplegia. Out of the presentation and discussion of papers and current research at these conferences, the well known, international journal, Paraplegia was born. Today, Paraplegia is the recognized journal of the spinal-cord injured and is printed and subscribed to by readers in more than three languages throughout the world. The scope of its coverage pertains strictly to the disabled who were paralyzed via spinal cord damage and does not provide information or technical guidelines regarding disabled athletes. In fact, according to Messner (in Stewart, 1983), the sportsmedical aspect of disabled athletics has only been a part of the European disabled sports organizations for about 20 years.

More recently, in the early 1970's Sports'N Spokes, a magazine for wheelchair sports and recreation was published bimonthly primarily for those with spinal cord injury, spina bifida, and some congenital defects. This popular journal contains articles and advertisements on wheelchair sports competitions, recreation, equipment, techniques, personalities and related topics. Although scarce, a few scientific articles directed towards the medical and physiological aspects of sports for the disabled have been published. These scientific articles, together with the medical articles published in Paraplegia and the sports interest articles printed in Sports'N Spokes comprise the limited literature on wheelchair sports and disabled athletes. Some of these researchers have recognized the important role sports medicine plays in the athletic careers and achievements of disabled athletes (Corcoran et al, 1980; Curtis, 1982; Stewart, 1983; and Botvin Madorsky and Curtis, 1984). However, with the exception of brief statements in a couple of these articles, the only sources of statistically sound data relevant to wheelchair sports medicine are the medical reports of disabled competitions, and the handful of sports medicine questionnaires that have been conducted.

In 1981, Curtis collected data on injuries to wheelchair athletes through a questionnaire that was mailed to subscribers of an American wheelchair sports magazine entitled, Sports'n Spokes. Out of the over 1200 questionnaires that were distributed, only 129 questionnaires, or less than twenty percent were returned (Curtis, 1982). Botvin Madorsky and Curtis (1984) presented data on wheelchair sports injuries that were based on the statistical data reported by Curtis in 1982. They stated that the most prevalent injuries sustained by wheelchair athletes were soft tissue injuries, blisters and skin lacerations or abrasions. The major sports injuries, such as fractures or trauma leading to further permanent disability, they claim were rare (Botvin Madorsky and Curtis, 1984, p. 129). The only other questionnaire concerning injury to wheelchair persons was administered in England to 708 members of the British Spinal Cord Association by Nicols et al (1979). Their return rate of 79.5% revealed that of the approximately 5% British spinal cord injured population sampled, 51.4% or 266 of the respondents suffered from pain on or around the shoulder. No further breakdown of the data, such as the nature and/or cause of the shoulder pain, was given by Nicols et al (1979). Part of the conclusion to Nicols et al's (1979) research was based on a comparison with another study. Unfortunately, the data for the incidence of injury in Nicols et al's (1979) study was compared to able-bodied data collected by Irvine et al (1964) on neck and arm pains in patients of a general practitioner. Based on the use of these patients as controls, Nicols et al (1979) concluded that people who are users of self-propelled wheelchairs are more liable to develop pain around the shoulders than any age group of the normal population.

No other studies or articles directly pertaining to sports injuries are available in the literature. However, in a study conducted in Montreal on 130 male wheelchair basketball subjects by McDonell et al (1980), it was reported that four out of the experimental subject group were, "unable to adhere to the training program due to pressure sores and/or bladder infection". No traumatic injuries were reported throughout the mild to moderately demanding exercise training study. Unfortunately, the completeness and the accuracy of the medical games records kept by the various sportsmedical specialists who accompany the competitors to the games, varies with the level of competition. Seldom are any formal accounts kept at the local or provincial competitions of the specific type of injury treated, the frequency of injury, or the sport in which the injury occurred. Occasionally an effort is made at international and national games to record some statistics of injury occurrence.

Most of the medical reports that are written to summarize the injuries that occur and the treatments that are administered to the athletes at the various competitions, are brief descriptive accounts which focus more on the facilities available and the materials used rather than the nature and cause of the injuries sustained. The physiotherapy report of the 1984 Paralympics held in Stoke-Mandeville, England describes the nature of the injuries that occurred by the number and type of injuries that were treated; for example, "blisters 5, abrasions 4". No data on the sport or the athlete's classification was presented (Mount, 1984).

In contrast to Mount's inadequate summary, the comprehensive Medical Report of the 1980 Holland Olympics prepared by athletic trainer, Wilcox (1980), presented statistics on the number of conditions treated by sport and by classification, and the specific type of treatments rendered. There were a total of twelve wheelchair athletes who suffered injuries throughout these games. Four reported muscle strains, tendinitis, or abrasions, while one athlete acquired spinal pain and another a metatarsal fracture. The fracture occured to a polio wheelchair athlete who received a plaster cast for his foot and was able to continue competing in all his events just as soon as the plaster cast had dried. The report of the Holland Olympics contained specific and statistically useful data that has not been found elsewhere in the literature. In addition, Wilcox included a copy of the treatment report forms used and the medical report form that contained the medical information for all competitiors. A summary of all the traumatic and hygenic problems that were encountered at the 1980 Holland Olympics and required treatments, were documented in the chief medical doctor's report. Of these, there were 35 minor abrasions treated including blisters, boils, lacerations and pressure sores. The total number of injuries to the Canadian team which required specific physiotherapy treatment talleyed to 167. The most frequently occurring injuries were muscle strains (19) and ligament sprains (16).

Although wheelchair sports are relatively new, they have developed rapidly. In their pursuit of excellence, wheelchair athletes have invented wheelchairs, developed techniques, modified sports equipment, and popularized wheelchair sports participation. As the number of elite wheelchair athletes increases, the competition intensifies, and the training goals of the wheelchair athletes become more difficult to attain. To meet these challenges and to reach one's full potential, athletes adhere to dedicated training regimes, that are balanced, personalized, and physiologically and technically sound. Since injury incidence is inevitable in all sports participation, the etiology of wheelchair sports injury is of interest not only to wheelchair athletes, but also their coaches, support staff, and interested others. This research study presents statistically sound data in a scientific format. Many means of prevention, possible causes of injury, treatment rendered, and several recommendations are discussed.

Chapter III

METHODOLOGY

A. Nature of the Sample

The sample for the study was comprised of 90 Canadian wheelchair athletes who had competed in wheelchair sports at the provincial, national, or international level in 1985, and who were active members in the Canadian Wheelchair Sports Association in 1985. The data was collected at several disabled athletic competitions held during the spring and summer of 1985 in cities throughout Canada. The survey data was grouped according to five different criteria: 1) competitive experience, 2) province of residence, 3) body parts injured, 4) sports where injuries occurred, and 5) disability classification. This study's data has been analyzed in three ways: according to the number of athletes injured (n=289), according to the frequency of injury by sports event (n=346), according to the frequency of injured body parts (n=328) (Table IV-II).

The age of the youngest competitor was 15 years and the oldest was 46 years old. Seventy athletes (80%) were between 15 and 34 years. The modal age (seven athletes) was 23 years. The average age of the wheelchair athletes in this study was 28 years old. This was well within the average age range 20 to 29 years which Chen and Lien (1985) stated was the age of the highest incidence of spinal cord injury (Chen and Lien, 1985, p.368). The ratio of male to female of all the athletes in the study approximated eight to one. This ratio is also a reflection of the sex ratio for the general population of spinal-cord injured people. From April 1984 to March 1985, 78.4% of spinal-cord injured in Canada were males. This national statistic is a male/female sex ratio also of eight to one (Bernauer, 1985). Although there was a higher percentage of spinal-cord injured males in the total sample population (8:1 ratio), within the group of spinal-cord injured the ratio of male to female approximated one (1:1).

The mean number of years of disability was 13 years. The modal length of disability was five years. While two athletes were competing after only 11 months and 12 months of the date of their disabling injury, sixty percent of the sample had been disabled between 3 to 13 years.

The percentage distribution of the total sample population by disability was 71.3% (two-thirds) spinal-cord injured, 13.8% (less than one quarter) amputee, and 14.9% les autres (Figure III.1). The les autres category includes all those with spina bifida, polio, cerebral palsy and other neurological and congenital disorders. Each of these disability organizations has devised their own number and/or letter system of classification based on their medical disability (Appendix F). Inspite of their medical classification, many disabled athletes who used a wheelchair to compete in sports, were also functionally classified. Their functional classification was dependent upon the evaluation of the wheelchair athlete within the environment of their sports event. The addition of this functional means of classification originated in direct response to innovative wheelchair designs.

In retrospect, wheelchair sports competitors are a gathering of many disability types. For the purpose of this study, these classes were split into three groups; 1) the paraplegics and amputees, 2) the quadriplegics, and 3) others (les autres). The percent distribution of quadriplegics in this study's sample population was 32.2%, while the paraplegics and amputees comprised 52.2%, and the remaining 15.6% were 'les autres' (Figure III.2).

B. Wheelchair Sportsmedicine Questionnaire

To investigate the etiology of sports injuries to Canadian wheelchair athletes through participation, training, and competition, the survey technique was chosen. A three page questionnaire was devised specifically for this study and is included in Appendix C. Some of the questions were adapted from the 'Wheelchair Sports Medicine Questionnaire' used by Curtis (1982) (Appendix D). The remainder of the questions were developed following a review of literature concerning wheelchair sporting activities, and in consultation with sportsmedicine and adaptive specialists, coaches, and wheelchair athletes.

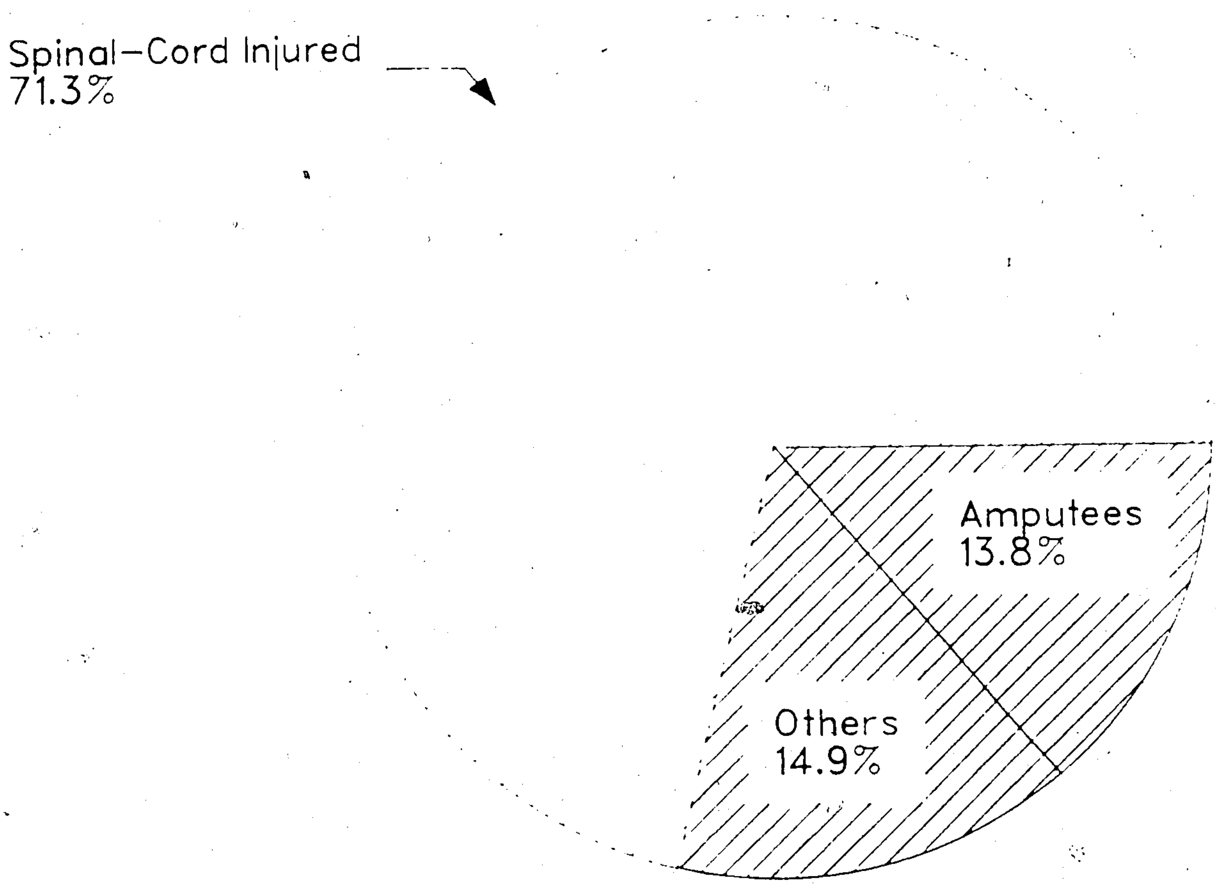


Figure III.1 Sample Population by Disability

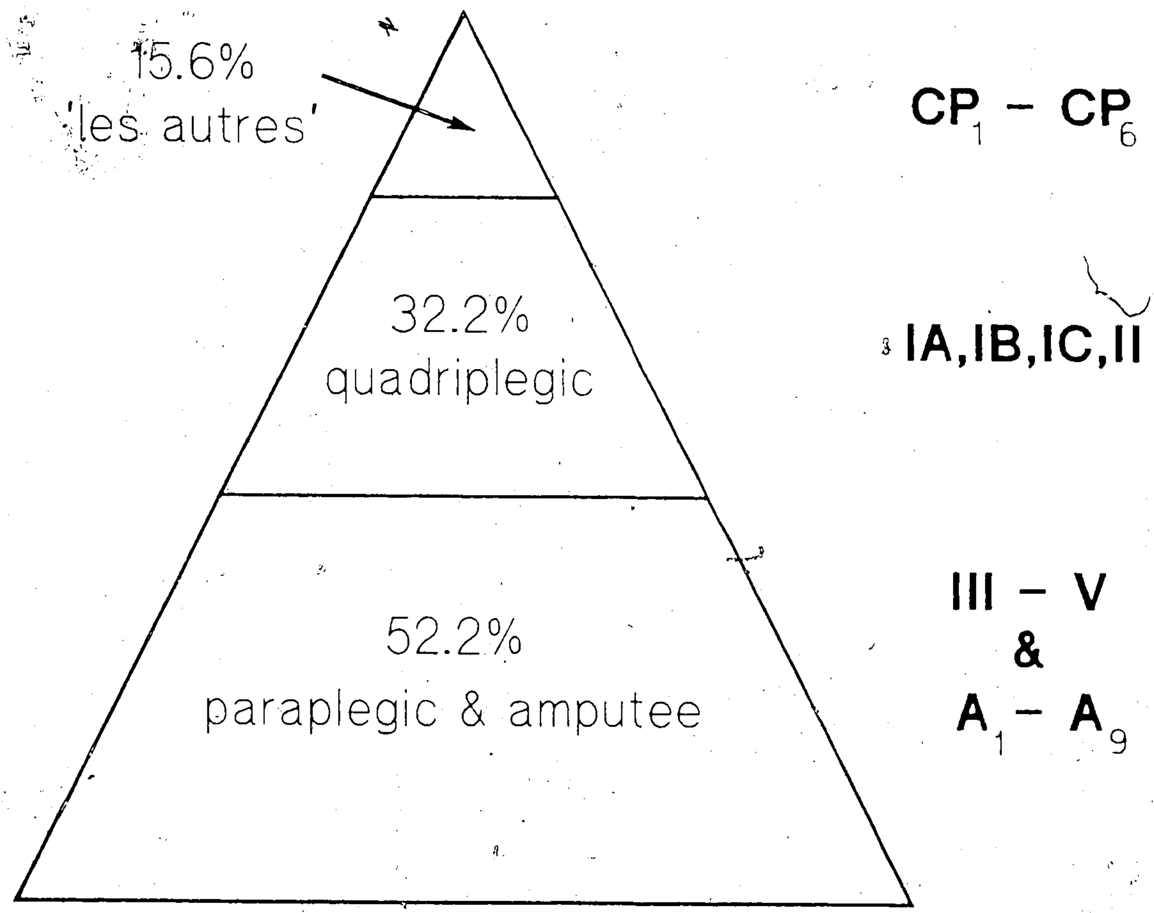


Figure III.2 Sample Population by Classification

The nature of the questions centered around the many extrinsic factors which could have led to wheelchair sports injury. Additional information regarding the type of wheelchair used, the hours spent training, and the number of competitions entered was also gathered. The format of the questionnaire included several closed questions accompanied by a few open-ended questions.

C. Procedures

The researcher administered each survey on a one to one basis with each athlete. This ensured that the purpose of the survey was understood by the athletes, and that they completed the surveys correctly. The 'Wheelchair Sportsmedicine Questionnaire' and the accompanying instruction sheet were distributed directly by the form administrator to the wheelchair athletes at the various competition sites across Canada.

D. Data Analysis

At the completion of the data collection in August of 1985, the data was transferred to a computer file. Basic descriptive statistics were computed using a Midas program. The analyzed statistics were presented using frequency tables, figures, and pie graphs which illustrated the injuries to specific body parts relative to: each sports event the athlete competed in, the location of the injuries, the frequency of injury occurrence, the treatment follow-up carried out, and the total injuries which occurred in each sport (Garrick, 1987). Other figures represented the statistics regarding the sex, age, disability, competition status, number of training hours and competition years, protective gear worn, and type of wheelchair used by the sample population.

Chapter IV

RESULTS AND DISCUSSION

> When it comes to reading the report of an empirical study...the layman reads the text and skips the tables, the researcher reads the tables and skips the text, as long as they agree with each other
>
> (T.Hireshi and H.Selvin, 1982).

A. Sports Experience

Overall, the 90 athletes participated, trained, and competed in sports for an average of 6 to 10 hours per week, and a maximum of 25 hours per week (Figure B.1 in Appendix B). Participants competed as wheelchair athletes in 80% of the 30 different sports events listed in the study, while 20% were recreational participants. Those sports with the greatest number of both recreational participants and competitive athletes included field events, track events, basketball, road racing, and swimming. The least popular sports were sledge hockey, water skiing, CP soccer, and badminton.

The number of competitive years ranged from 1/2 to 14 years with the mean years of competing as 4 1/2 years. Over a maximum of 14 years, the number of competitions entered by the athletes ranged from 2 to 210. The athletes competed in an average of 5 competitions per year. This study documented the numbers of athletes who competed at three levels of competition; provincial, national and international. The greatest number of athletes (60%) competed at the national level, with only 34% having competed at the international level. (Figure IV-I).

Further to this information, statistics on the mean number of years athletes competed internationally were calculated. Ranked, according to the athletes' greatest to their least average number of internationally competitive years, the sports were: basketball and club throw (6 years), track sprints and middle distance (4 years), and weight-lifting (3.5 years). Those sports with an average of 2 years or less of international competition included tennis, road racing, table tennis, rugby, and racquetball. Sports in which the greatest number of athletes had competed at the international level were ranked as follows: road racing (14),

Table IV:1 High Participation in Wheelchair Sports

SPORTS EVENTS (n=30)	*# OF ATHLETES PARTICIPATING per sports event*	*% OF ATHLETES INVOLVED (N=90)*
Field Events (4)		
discus	47	52.2%
shotput	44	49.0%
javelin	38	42.2%
club throw	20	22.2%
Track Events (2)		
sprints	61	68.0%
middle distance	34	38.0%
Basketball	56	62.2%
Road Racing	36	40.0%
Swimming	35	39.0%
Table Tennis	34	38.0%
Rugby	28	31.1%
Weight Lifting	24	27.0%
Tennis	23	25.6%
Archery	21	23.3%
Kayak	19	21.1%
Volleyball	16	18.0%
Softball	10	11.1%
Riflery	9	10.0%
Sailing	7	8.0%
Riding	7	8.0%
Bowling	6	6.6%
Slalom	4	4.4%
Sledge Skiing	4	4.4%
Outrigger Skiing	3	3.3%
Racquetball	3	3.3%
Scuba	3	3.3%
Snooker	2	2.2%
Sledge Hockey	1	1.1%
Badminton	1	1.1%
Water Ski	1	1.1%
Soccer	1	1.1%

basketball (13), track sprints (11), and track distance (10). Although road racing is a relatively new sport in international competition, it is a very popular sport. Several other new wheelchair sports to soon appear on the international competitive scene include: outrigger skiing, sledge skiing, softball, and racquetball.

B. Regional Statistics

Canada's ten provinces (the territories were not surveyed) were divided into three regions which included athletes from British Columbia, Alberta, Saskatchewan, and Manitoba (the West); Ontario and Quebec; and the Atlantic provinces. Nearly one half (54.4%) of all the athletes were from the West, 26.7% (or one quarter) from Ontario and Quebec, and 18.9% from the Atlantic provinces (Figure IV.1). The discrepancy in athlete density by geographic location of this study's wheelchair athletes was not likely to be a true indication or reflection of the population density distribution of all Canadian wheelchair athletes. Rather, the collective contributions of each region's physical size, their availability of coaches, and the characteristic climate of each region, were influential factors in the wheelchair athletes' choice of provincial residence. The athletes' are unlikely to have moved to provinces to obtain better quality acute care because spinal cord injury care centers are located in major cities throughout Canada. The percentage of male to female athletes for each region was consistent with the 8:1 ratio of the total sample population. Ontario and Quebec had the highest percentage of national level competitors at 79.2%, while the greatest percentage of international athletes were from the West at 46.9%. The consistently warmer months, characteristic of Canada's west coast climate, may have influenced the more serious wheelchair athletes to move West. Training outdoors all year long has its advantages. However, the recent popularization of wheelchair ergometers and accessible training centers has made indoor training a viable alternative for dedicated wheelchair athletes (Gass, 1981; Steadward, 1979; DiCarlo, 1982). Thus the development of well-equipped, accessible, indoor training facilities has perhaps lessened the urge for wheelchair athletes to move to the West coast where the grass is green year long, and the winters less cold. The high percentage of international athletes from the west was perhaps a compliment to the regional coaches. However, as there was no established system to acknowledge or assess the credentials of wheelchair sports coaches, it was difficult to make claims about regional coaching expertise, or regional concentration of elite head coaches.

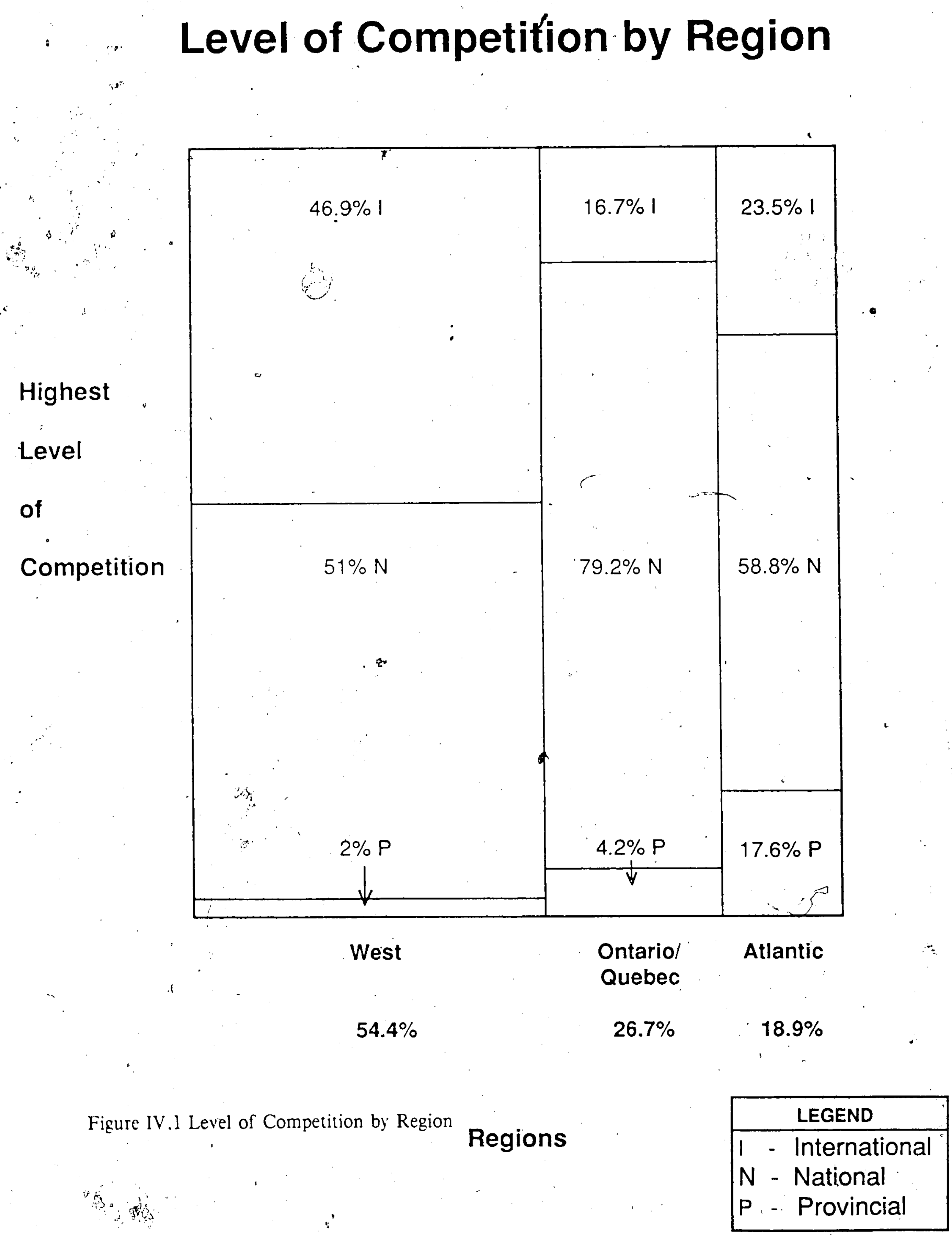


Figure IV.1 Level of Competition by Region

The athletes from the Atlantic provinces primarily had experience competing at the provincial level. Perhaps, there was a correlation between their infancy in wheelchair sports development, and their inexperience in wheelchair sports competitions. As 1985 was the first year of the Maritime regional games, perhaps it was the first opportunity for many of these athletes to compete. The less densely populated cities and towns together with the abundance of ocean between provinces results in a natural isolation of wheelchair competitors within the Atlantic provinces. It is difficult to perform at a national or international level without regular competitions to compete in and competitors to compete against.

Regionally, 55% of the athletes from the West spent more than 10 hours per week involved in wheelchair athletics, while the athletes from both of the other regions were represented by only one third of their athletes who trained for greater than 10 hours. This statistic pointed to a relationship between the number of training hours and the level of competition. The west region had both the greatest percentage of international athletes, and the greatest representation of athletes (16.7%) who trained for at least 10 hours per week.

C. Wheelchair Sports Injuries

Table IV-II is a summary of the number of athletes injured (n=289), the frequency of injury by sports event (n=346) and the frequency of injuries by location (n=328). Thus each of the 90 athletes not only injured more than one body part, but sustained injuries in more than one sports event. Overall, the injury statistics underestimated the total frequency of sports injuries to all Canadian wheelchair athletes. Due to the nature of sampling from four competitions in Canada rather than an ongoing injury recording system, the information was dependent upon the memories of the athletes. Thus the types of injuries that were recalled together with the popularity of some sports, may have resulted in a more accurate representation of some injuries. (Table IV-II).

Table IV-II: Summary of Reported Injuries

INJURY TYPES REPORTED (*n=15*)	*NUMBER AND FREQUENCY OF INJURIES* by Athlete (*N=90*)	by Frequency of Sports Event Participation (*n=346*)	by Frequency of Body Parts Injured (*n=328*)
Blisters	67	86	82
Abrasions	62	78	72
Muscle Strains	47	53	56
Tendinitis	27	37	29
Bursitis	14	17	14
Muscle Bruises	14	15	17
Lacerations	11	11	13
Bone Bruises	10	12	10
Pressure Sores	8	[illegible]	7
Fractures	7	7	7
Concussions	7	7	6
Inflammation	5	5	6
Eyes	4	4	4
Teeth	4	3	3
Dislocations	2	2	2

1. Sports the Injuries Occurred In

The wheelchair sports associated with the least number of injuries were slalom, riflery, and racquetball while basketball, track, and road racing reported the greatest number of sports injuries (Table IV-III). the number of injuries in each sport was calculated with reference to the number of athletes participating in that sports event, a more accurate incidence of injury rate per athlete was established (Figure IV.2). While 12 sports recorded no injuries at all, four sports events had more than one injury per athlete. These high injury incidence sports were: basketball (1.91), road racing (1.17), rugby (1.14), and track (1.12). Coincidentally, these four sports were also among the 10 most popular wheelchair sports (Table IV-I). Ranked by greatest to least popularity the high participation sports were: field, track, basketball, and road racing. The relationship of high participation and high injury incidence in sports events was not true amongst all wheelchair sports. For example, although field events were popular with as many as 149 athletes participating, the incidence of injury was only 0.19 injuries per participant (Figure IV.2). This low incidence of injury established field events amongst the safest wheelchair sports events in terms of sports injury incidence. However, when A plausible explanation for the low incidence of injury in field events may have been related to the non-contact, individual participation typical of field competition events. In addition to the abundance of technical staff organizing the field events, there was sufficient open space to ensure that poorly aimed throws did as little damage as possible.

In contrast to the low incidence of injury in field events and its popularity, basketball is perhaps the sport with the greatest likelihood of sports injury incidence. Less popular than field events, basketball boasted only 56 participants, yet nearly every athlete was injured twice. Contrary to field events, basketball is a contact team sport characterized by defensive plays, blocking, picks, and the inevitable fouls, in an effort to score baskets and to prevent the opponents from scoring (FIBA Federation International Basketball Association). The nature of the game involves passing, throwing, bouncing, or dribbling the ball within the established rules and regulations of the sport. There are many sources of injury mechanisms in basketball including: player collisions, wheelchair spills, mechanical failure of the wheelchair, and occasionally misdirected basketballs. Although both field and basketball were popular sports, the nature of each sports event partially determined the variety and extent of wheelchair sports injuries that occurred in each sports event.

2. Body Parts Injured

The 90 athletes reported a total frequency of 328 injuries to 25 different body parts. Some of the body parts were collapsed into one or two categories. The head and face category comprised sports injuries to six body parts: the head, eye, ear, nose, lip, and teeth. Expectedly, as the sample population was comprised of wheelchair athletes who primarily use their upper bodies for activities, few lower body injuries were recorded (Figure IV.3). Thus it was possible to collapse the seldom injured lower body parts into one category. This category entitled, 'lower body', consisted of injuries to seven body parts: the thigh, knee, calf, foot,

Table IV-III: Wheelchair Sports Injury by Sports Event

SPORTS EVENTS (n=18)	*# OF INJURIES REPORTED*	*% OF INJURIES REPORTED* (N=346)
Basketball	107	30.9%
Track	106	30.6%
Road Racing	42	12.1%
Rugby	32	9.2%
Field Events	28	8.1%
Tennis	17	4.9%
Weight Lifting	6	1.8%
Swimming	4	1.2%
Racquetball	2	0.6%
Riflery	1	0.3%
Slalom	1	0.3%

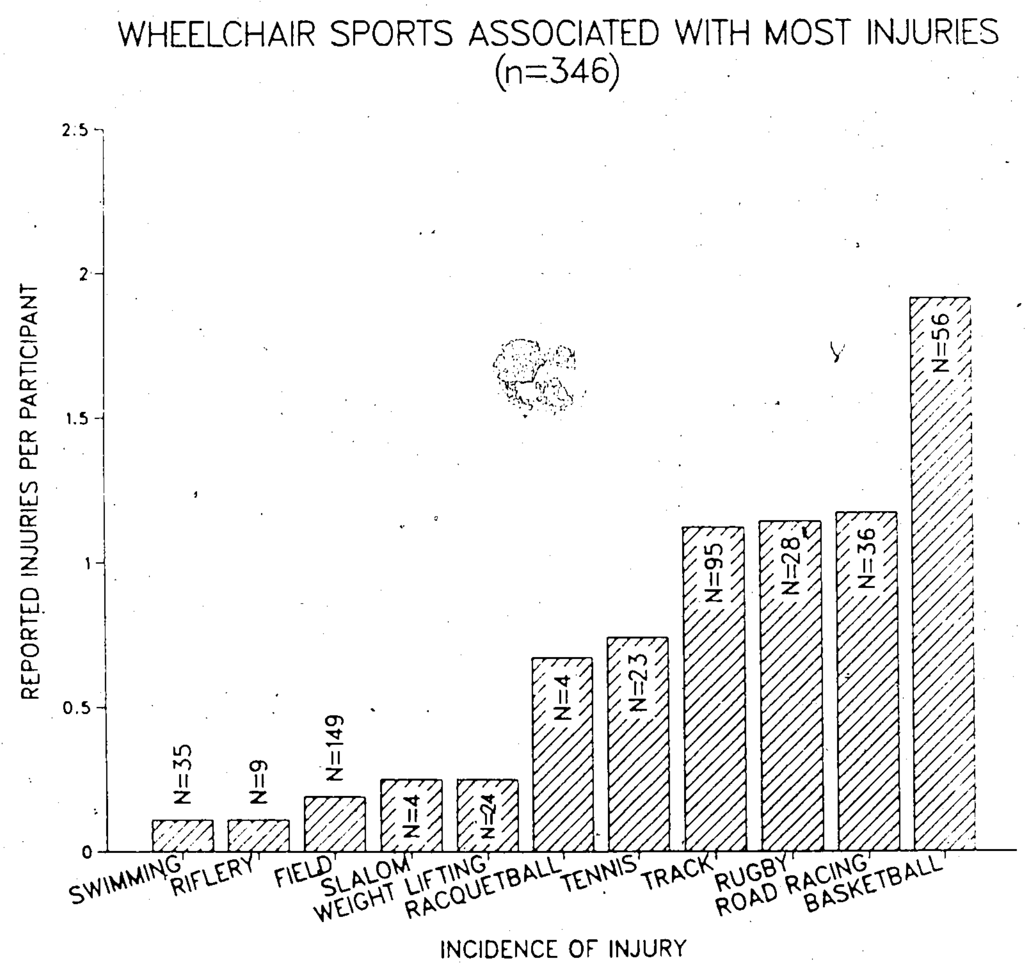


Figure IV.2 Injury Incidence of High Participation Wheelchair Sports

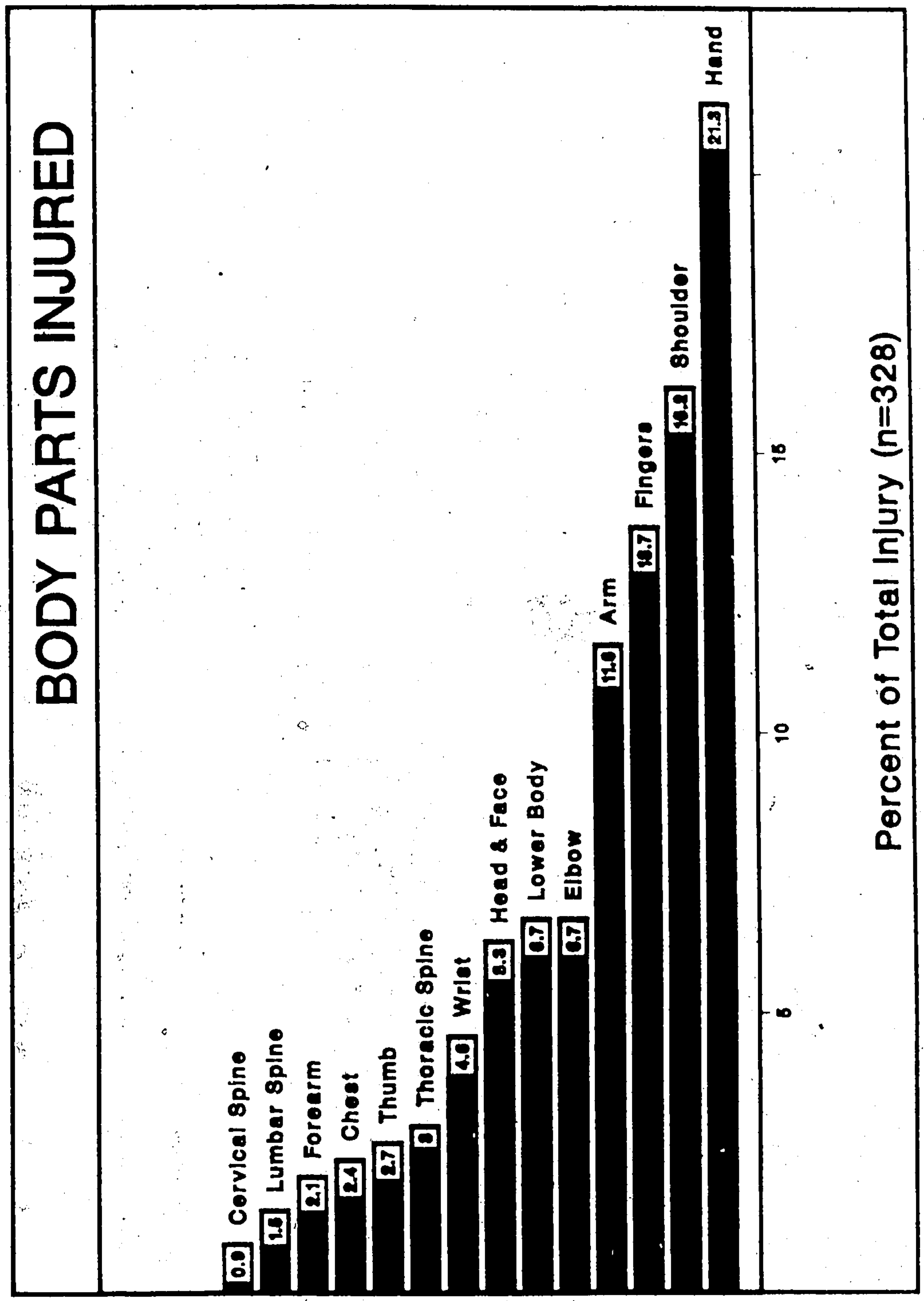


Figure IV.3.Location of Injuries

toes, ankle, and hip.

Ranked as most injured to least injured, the four body parts which most commonly sustained injury throughout all wheelchair sports were: hand (21.3%), shoulder (16.2%), fingers (13.7%), and arm (11.6%) (Figure IV.3). Apart from these upper body injuries and the injuries to the combined categories of lower body, head and face, both the elbow (6.7%), and the wrist (4.6%) were also frequently injured. It is likely that the concentration of upper body sports injuries reported was due to the nature of wheelchair sports, specifically the biomechanics of wheelchair propulsion. To propel a wheelchair demands the use of the upper body. The demands placed on these relatively small upper body parts by the contracting muscle groups results in great stress on the surrounding joint structures. It is therefore easily justified that the high frequency of wheelchair sports injuries to the hand, shoulder, fingers, and arms, were not only acute soft tissue injuries but also chronic or overuse injuries.

Of the 25 body parts injured, the least number of injuries occurred to the cervical spine (0.9%) followed by the lumbar spine (1.5%)(Figure IV.3). The low frequency of neck and back injuries is related to the characteristics of competitive wheelchairs and the typical types of impact forces which caused wheelchair sports injury. In able-bodied athletes, injury to the head, neck (cervical spine), or other part of the spine may be a result of head-on collisions in able-bodied sports such as football or rugby (Havkins, 1986, p.111; Cantu, 1986, p.75; Mueller and Blyth, 1986, p.139). Frequently, the point of contact of a head-on collision in able-bodied sports is the head. In contrast, 'head-on' collisions in wheelchair sports involve two wheelchairs colliding. The initial point of contact is the wheelchair and then, secondarily, the athlete. Thus the force of impact is transmitted through the wheelchair frame, where a large proportion of the energy is absorbed, and then dispersed or deflected. The energy dispersed from the point of contact follows the body's long bones, which include the appendages and the backbone or spine. Since the neck is located at quite a distance from the original point of impact, neck injuries resulting from wheelchair collisions were unlikely. The statistics support this argument as 0.9% of sports-related neck injuries were reported.

Although the cause of neck injuries may not have been due to wheelchair collisions, athletes who tipped backwards and fell with or out of their wheelchairs, may have accounted for the few reported neck injuries. In falling backwards in a wheelchair the arms attempt to break the fall, but often the first point of contact made is the back of the head with the floor. In this type of injury, the neck may well have shared the brunt of the impact forces. The lumbar spine was also infrequently injured. Perhaps this low incidence of lumbar spine injury was because the lower back is well protected by the seat upholstery or seat bucket of sports wheelchairs.

3. Types of Sports Injury

Any injury is caused by either extrinsic or external forces or by intrinsic or internal forces, which become great enough to injure or to cause bodily harm. Characteristically, the forces involved in sports cause sports injury to different body parts in a variety of sports events. The rules, and objectives of each sports event are unique. The differences in the sports specific rules, objectives, equipment worn or used, and technique all influence the types of sports injury which occur most frequently in each sports event.

This study did not collect data on the causes of sports injury to wheelchair athletes. As noted in the questionnaire (Appendix C) the data collected on each injury type primarily included information on the body parts injured and the sports each injury occurred in. The rationale for not surveying the cause of injury was logical. First, the more experienced athletes had been actively involved in a variety of wheelchair sports competitions at the international and national levels for a number of years. It was difficult for many of these experienced athletes to accurately recount all of their sports injuries that occurred throughout their entire wheelchair athletic career. It would have been unlikely for them to also have recalled the causes of injury. Secondly, injuries often have an insidious onset. Finally, exempting some acute injuries, many mechanisms of injury are obscure. The combination of training, recreational participation, and athletic competition together with the variety of sports participation cloud the exact causes of sports injury. Chronic or overuse injuries occur as a result of increased stress over a period of time. "It takes a skilled, experienced, and knowledgeable sports medical authority to record the complete medical history and deduce an accurate explanation of injury mechanism" (Portis, 1985, p.6).

The patterns or trends of injury occurrence within specific sports events were often explained by the particular technique characteristic of that sports event. The trends for both the frequency of body parts injured, and the frequency of injuries by sports event participation were illustrated for each of the six common injuries (Figures IV.5-IV.10). Reasonable suggestions for the possible causes of injury were discussed for each of the six common sports injury types in wheelchair sports.

The distribution of the 15 injury types was reported as a percentage of the total number of injuries sustained by the 90 wheelchair athletes in this study (n=289). The six most common injuries were blisters (23.2%), abrasions (21.5%), muscle strains (16.3%), tendinitis (9.3%), bursitis (4.8%), and muscle bruises (4.8%) (Figure IV.4). These soft tissue injuries damaged structures which included the skin, the underlying musculature, tendons, and bursae. The primary cause of soft tissue disruption in wheelchair sports were extrinsic forces such as the forces involved in collisions, decreased friction, or falling.

Although not as common in wheelchair sports, injuries caused by intrinsic forces were reported. Intrinsic forces cause injury which results from a sudden imbalance in internal forces often within the musculotendinous complex. A combination of both intrinsic and extrinsic forces in wheelchair sports results in overuse or chronic injuries. Repetitious movement, such as that required of the shoulder, elbow, and wrist joints in wheelchair propulsion, was the common mechanism of overuse wheelchair sports injuries. In wheelchair sports, the stress of repetitive movements demanded in specific sports skill performance results in bursitis and tendinitis injuries to the upper body joints. In wheelchair athletes, the shoulder, elbow and wrist joints of the upper body were constantly performing repetitious actions. For example; the wheeling motion, the throwing action in field events such as javelin, and the freestyle stroke in swimming demanded similar shoulder joint actions. Thus the surrounding joint structures and musculature became stressed and weakened; a situation which

MOST COMMON INJURIES IN WHEELCHAIR SPORTS
(n=15 injury types) (n=32 sports)

as a percent of total injuries (n=289)

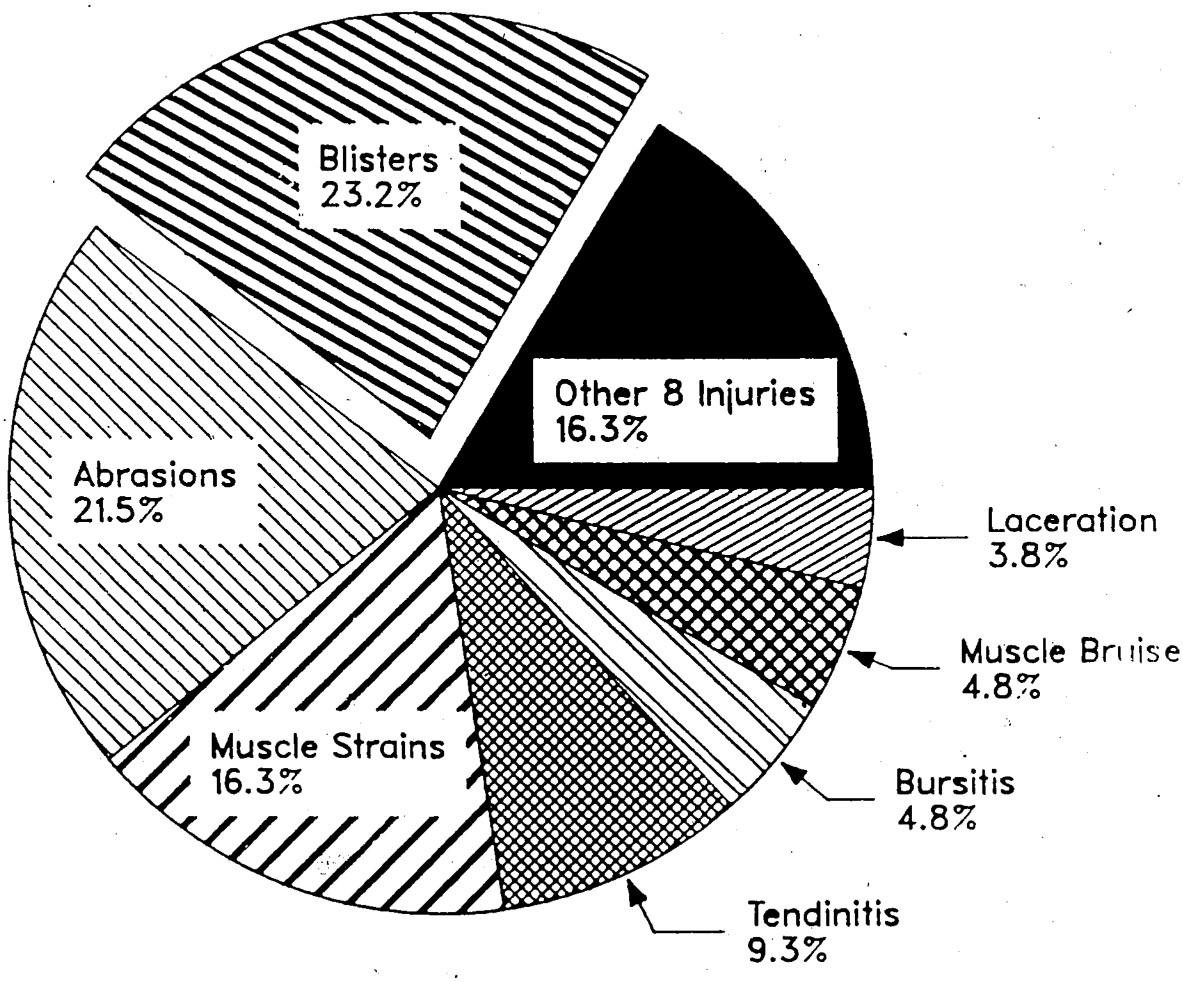


Figure IV.4 Most Common Injuries in Wheelchair Sports: as a percent of total injuries predisposed the athlete to injury and if injured, led to chronic injury.

(i) Blisters

The most common sports injury sustained by wheelchair athletes across all disabilities was blisters (21.2%). Nearly all (91.4%) of the blisters reported occurred to the hands (54.8%),and fingers (36.6%). The remaining 8.6% of the blisters occurred to three other body parts: thumb (6.0%), arm (1.2%), and forearm (1.2%) (Figure IV.5). A common location of blisters in able-bodied athletes is across the extensor or palmar surfaces of the hand and fingers (Cabrera and McCue, 1986, p.696). Similiarly, in wheelchair athletics, blisters commonly were located on the index finger, thumb, and the heel of the hand's palmar surface. This pattern of blister occurrence in wheelchair athletics closely resembled the blister pattern in able-bodied baseball pitchers. It has been well documented in the literature that the index finger and the thumb are blistered in fastball and breaking ball pitches (Cabrera and McCue, 1986, p.696). Excluding individual technique, the hands in wheelchair propulsion especially the thumb and index fingers, were in contact with the wheelchair hand rims and/or wheels. This continual hand rim contact in wheelchair propulsion yielded blisters which developed from acute frictional stresses across the epidermal layers of the skin covering the thumbs, fingers, and palm of the hand.

Blisters frequently were sustained by athletes who had participated in track (39.5%), basketball (31.4%), road race (11.6%), and three other sports: rugby (8.2%), tennis (5.8%), and field (3.5%) (Figure IV.5). More than one quarter (25.6%) of all athletes developed blisters through participation in more than one sports event. The cross-over of stress from similiar wheeling techniques in a variety of sports likely increased the occurrence of blisters throughout the sample population. The greatest frequency of blisters sustained by track and basketball players was likely to be caused by the characteristic short, quick arm strokes used in track sprints, and the powerful stopping, starting, and agility moves typical of wheelchair basketball players.

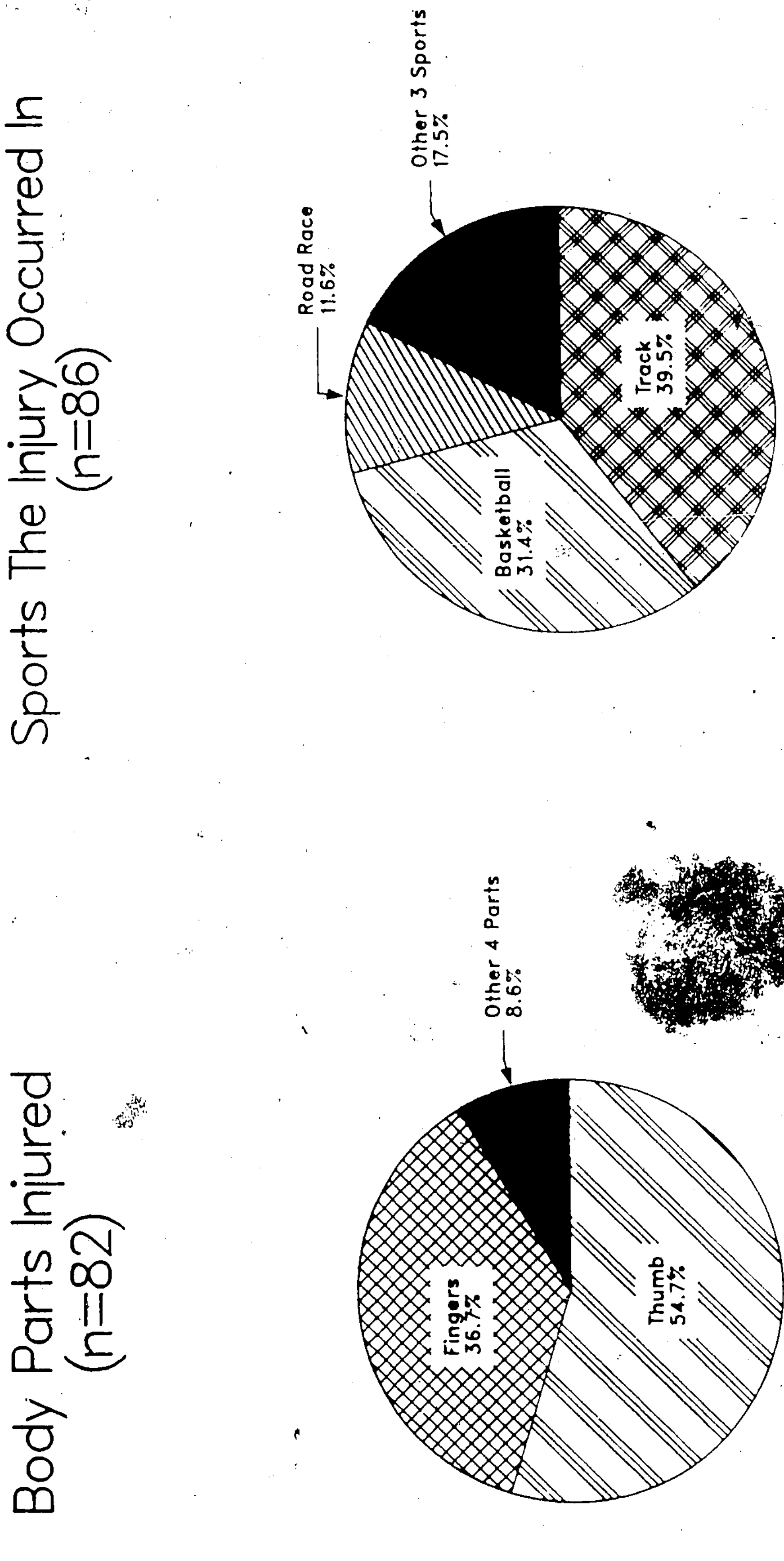


Figure IV.5 Blisters

To start the wheelchair in motion the athlete must overcome inertia. The great deal of force required to initiate momentum was often applied directly to the wheels of the wheelchair rather than the hand rim. The wheels, especially in outdoor track events or road races were not only rough with tire traction grooves but often contained debris embedded in these grooves. The use of these debris-filled rough tires for initial hand contact would have further contributed to the development of friction leading to worn out gloves and blister formation.

In stopping the momentum of a wheelchair abruptly to avoid debris on the race course surface, to stop at the race finish, or to change directions of travel in basketball, athletes apply pressure or force directly to the wheels. The hands immediately contact the wheels and serve as brake pads to stop movement abruptly. The backward direction of force imparted to the wheels by the hands occur simultaneously with the absorption of deceleration energy of forward movement. The deceleration energy both at the finish of a road race or track event, and throughout basketball games is great. This energy was absorbed in track events and road races through the gloved hands of these wheelchair athletes, and in basketball by the players' bare hands (Plate IV.1). In contrast, although gloves were commonly worn in track events and in road races, basketball players preferred to use their bare hands. They claimed that the ungloved hand gave them a greater 'feel' for the ball which was required for shooting accuracy (Griffin and Minor, 1986). Without a glove, it was likely that more blisters would have been sustained by basketball players because of the increased frictional stresses applied directly to the bare hand in deceleration.

However, even though basketball players did not use gloves, the gloved track athletes still reported a higher frequency of blisters. Although taped gloves were worn in track events and road races, blisters still occurred amongst athletes of all years of competitive wheeling experience. In fact, there was a 10% higher frequency of blisters reported in track events than in basketball. Either the track athletes' gloves contributed to blister formation, or perhaps the weather influenced blister formation in track events.

Most basketball games are played on indoor courts without the influence of the weather. However, track events are commonly held outside under the influence of the variable and often unpredictable environment. On hot days, the track surface absorbs the heat of the sun's rays. The subsequent rise in temperature of this surface gives off heat which is perhaps absorbed by the black wheelchair tires. When the athletes' hands make contact with the tires, energy in the form of heat is transferred to the gloved hand. This energy together with the energy of friction from deceleration may speed up the wearing away both of the layers of taped glove and the underlying skin layers (Plate IV-1). This perhaps explains why nearly one-third of all track injuries, and almost one quarter of all road racing injuries reported were blisters (Appendix G:2, G:3).

Road racing reported only about one-third of the blisters which occurred in basketball or track (Figure IV-5). Although the wheelchair stroke used in all three sports is similiar, there are differences in the length of handrim contact, and the frequency of stopping and starting within each sports event. In the shorter distance track events, the athletes typically used smaller hand rims which allowed the hand, fingers and thumb to remain in constant contact with the hand rims (Higgs, 1983, p. 230). The high speeds in sprinting were obtained by the repetitive, short, swift propulsive strokes used. In contrast, few long distance marathon wheelies or road racers kept their hands in constant contact with the hand rims for the entire race. This accounted for the lower frequency of blisters reported in road racing. The varied terrain of uphills, flats and downhills allowed wheelchair road racers to alter their hand grip. Often on the downhill sections of the race, athletes rested their arms forward on the front caster(s)' cross bar. The rest break for the gloved hands perhaps allowed the 'hot spots', announcing the development of a blister, to cool down (Klafs and Arnheim, 1985, p. 424). Although taped gloves were worn in track events and road races, blisters still occurred amongst athletes of all years of competitive experience.

Of the eighteen athletes in the sample population with less than two years of competitive experience, 50% suffered blisters, while 76.3% of those 38 athletes with two to four years of competitive wheelchair sports experience suffered blisters. The highest percentage of blisters (85.3%) occurred to the 34 athletes with greater than four years experience. Of all those who developed blisters through sports, 45.5% have greater than 4

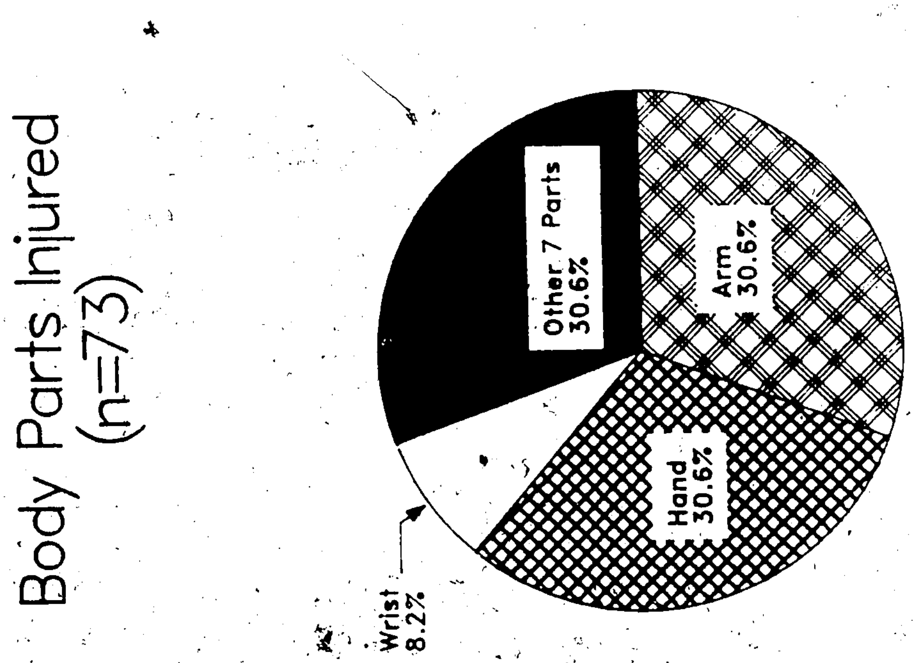
Plate IV.1 Wheelchair Sports Gloves

years experience, 36.4% have 2-4 years experience, and 18.2% have less than two years of competitive experience in sports. These statistics suggested that blisters did not disappear from an experienced athlete's career. With an increase in the number of competitive years, there was an exponential increase in the occurrence of blisters to these athletes. Perhaps this was because blisters are extremely common in athletes who require significant repetitive use of their hands (Cabrera and McCue, 1986, p.697).

(ii) Abrasions

Abrasions are common conditions in which the epidermal and dermal skin layers are worn away by scraping against a rough surface (Klafs and Arnheim, 1985, p.250). In wheelchair sports, the possible sources of the rough surfaces which caused abrasions included: the terrain, the wheelchair wheels (especially if they carried dirt and foreign materials), wheelchair brake levers, arm push handles, spokes, and other rough edges of the wheelchair frame. The mechanisms of injury resulting in abraded skin were falls to the ground, collisions with opponents' wheelchairs, or contact with the wheelchair frame.

The body parts most frequently abraded included the arm (30.6%), hand (30.6%), wrist (8.2%), and seven other body parts. These other body parts that suffered abrasions were: elbow (6.9%), fingers (6.9%), chest ([illegible]), shoulder (4.2%), forearm (2.8%) and thoracic spine (2.8%) (Figure IV.6). The high frequency of abraded arms was largely attributed to the cambered wheels of the individually designed track chairs. The wheels of these chairs are slanted outwards creating a greater base of support. The camber together with the smaller hand rim size, and the fit of the wheelchair, helped the track wheelchair athlete to keep all their wheelchair wheels in contact with the track surface at all times (Plate IV.2). Often the centrifugal forces at the tight corners of tracks or around corners in road races, caused the athletes to tip onto the inside wheels of their swiftly moving wheelchairs. The greater base of support provided by the cambered wheels was thought to have combatted these forces and kept the wheelchairs upright as the athletes maneuvered their wheelchairs around corners at high speeds. The latent effect of the cambered wheels was abraded skin of these



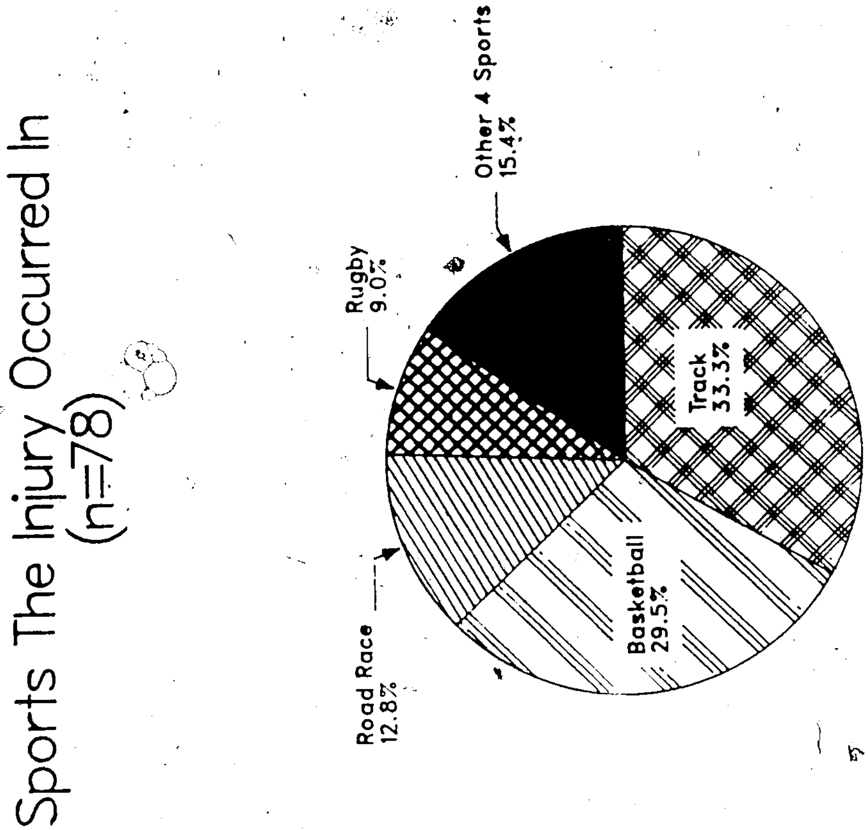


Figure IV.6 Abrasions

track athletes, where the wheels touched the inside chest wall and the inside of the arms.

Abrasions comprised 17.9% of the total injuries sustained by field athletes (Appendix G:5). Perhaps quadriplegics accounted for a proportion of the arm abrasions. The quadriplegics' lack of good motor control or balance forced these athletes to use their arm push handles for support in the throwing events. Typically, these athletes gripped around the wheelchair push handle with the inside of the elbow of their non-throwing arm. This position allowed the quadriplegics a greater range of motion in the cocking phase of throwing, supported their body position throughout the release phase and finally, absorbed the forces of the deceleration phase of the throwing motion. The resultant exposure of the inside of the elbow to the rough surface of the arm push handle caused abrasions to the arms of these athletes. It should be noted that the use of these push handles for support was probably not isolated to field even[illegible] wrist and finger flexors, this technique was commonly used to pull the quadriplegic's body back in the chair when they slid forward.

One of the major mechanisms of hand abrasions in wheelchair sports was falls. Many of the wheelchair athletes strapped their legs into their chair to restrain their involuntary leg tremor or movement. The athlete and the wheelchair thus become one unit. [illegible] athlete fell, their only means to break their fall was their outstretched arm and hand. The resultant meeting of the racing surface abraded the hands.

The wrist ranked third in frequency of abrasions (Figure IV.6). Perhaps this relatively high frequency of wrist abrasions was unique to the quadriplegic athlete. Their technique of wheelchair propulsion involved the application of force to the hand rims and wheels by the ventral aspect of the wrist and hand. This popular 'back-handed' technique was effective for the quadriplegic because it used wrist, shoulder, and forearm muscles which the high level quadriplegic had under voluntary control (Alexander, MJL, 1985, p.1). At the point of contact of the wrist with the wheel and handrim, the glove and often the underlying skin are worn away. This study found a high frequency of left arm and right wrist abrasions in all track athletes. This injury pattern correlated directly with the comments made by Colin Higgs (1983). Higgs, a Canadian biomechanist, has studied wheelchair propulsion and wheelchair stroke technique. He reported that the inside arms (left) on the track resisted the movement around a track corner, while the outer arms (right) assisted the athletes' forward momentum in a clockwise direction (Higgs, 1983, p. 232). Another rationale for this pattern of wrist abrasions is the method quadriplegics use to transfer into and out of their wheelchairs. Lacking wrist flexion, quadriplegics transfer by supporting their body weight on the anterior surface of their wrists.

Perhaps the wheelchair propulsion technique used on the track explained the injury pattern of the wrist, hand, and arm abrasions in this study. As the track athletes increased the force application of their right wrist and arm, two objectives were achieved. First, the chair was directed in a counter clockwise direction and second, the reduction in speed was minimal. Concommitantly, the resistance of the inside arm caused the wheelchair track athletes to alter their body position. As the outside wrist and hand moved downward and forward on the right hand rim, the inside arm probably applied a backwards force on the inside handrim and wheel. The resultant rotated body position caused a higher frequency of right wrist, right hand, and left arm abrasions.

Approximately two-thirds of those who suffered abrasions competed either in track (33.3%) or basketball (29.5%); 12.8% competed in road racing, and 9% in wheelchair rugby. The four other sports where abrasions were sustained included: field (6.4%), tennis (6.4%), racquetball (1.3%), and swimming (1.3%). Twenty-one percent or 19 persons out of the study had abrasions in more than one sport (Figure IV.6).

The road racer, who attained great speeds wheeling downhills on the race courses, often considered themselves lucky to have wheeled away from a spill with 'only' abrasions, instead of broken bones or other more serious injuries. Wheelchair athletes have clocked speeds on race courses in excess of 33 mph (Ierretti and Vince, 1986). The abrasions sustained at such high speeds would be similiar to the 'road rashes' (abrasions) common to able-bodied cyclists who have crashed.

In basketball and rugby, hands and wrists could have been abraded in scrambling for a loose ball. The hands may have been abraded on any rough part of the wheelchair frame.

bolts, uncovered spokes, or on the brake lever. In rugby the wheelchair is often equipped both with anti-tip wheels and with brake levers for safety purposes. The handles or levers of the braking device are often long metal extensions located at the front of the wheelchair to enable the quadriplegic athlete, who lacks finger flexors, to grip easily. Other athletes may have abraded their hands on wheelchair brake levers in rugby games or occasionally on basketball wheelchairs. Other sources of hand abrasions in rugby players is the rugby ball. Although the ball does not have rough surface, the nature of the game and the poor innervation of the quadriplegics' hand and fingers, dictate the technique frequently used to pass the rugby ball. The athletes bat the ball much like an underhanded serve in volleyball. The continual beating on the same hand surface area wears away the skin. This skin in poorly innervated areas is often slack, sometimes lacks good sensation, and thus is more susceptible to abrasion (Cabrera and McCue, 1986, p.696). Cabrera (1986) stated that "wheelchair athletes require gloves to prevent injury to insensitive areas of their hands" (Cabrera and McCue, 1986, p.696). Although many of the quadriplegic road racers wore gloves, few rugby players had adopted gloves as part of their game uniform. Perhaps their rationale was much the same as the basketball players who were concerned about losing the 'feel' of the ball if they wore gloves.

The experienced group of athletes, with more than four years experience, had the highest percentage of abrasions. Approximately 80% of the 34 athletes in the sample population with 4 years competitive experience sustained abrasions. Perhaps the more experienced athletes sustained more abrasions because they were more likely to take risks. Based on their tremendous skill and knowledge of sports, they perhaps had already discovered their own limitations, and willingly challenged themselves. In basketball for example, the more experienced athletes perhaps reached further for the basketball when defending their opponents, reached their arms higher to block the shot, or pass, and in all cases risked tipping, falling or otherwise abrading themselves in the game.

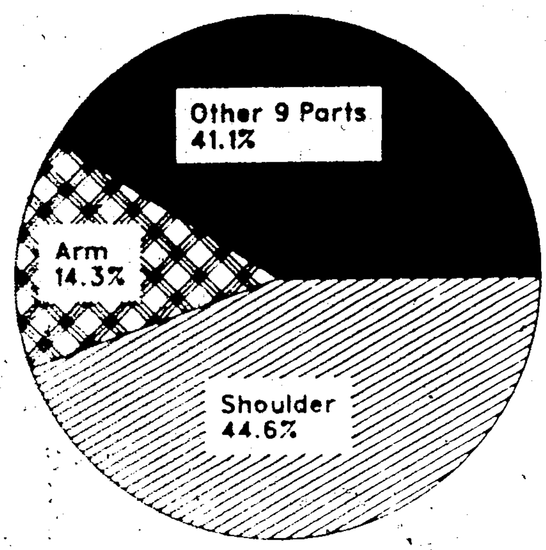
(iii) Muscular Strains

Muscle strains, the most widespread injury, occurred to 11 different body parts of athletes who participated in nine different sports events. Most often a muscular strain is produced by an abnormal muscular contraction. There are three main mechanisms of muscular strains: 1) sudden overstretching, 2) repetitive stress and 3) tortional stress or abnormal muscle contractions. In able-bodied athletes the highest incidence of muscle strains occurred to the hamstrings, gastrocnemius, quadriceps, and hip flexors; with few upper body muscle strains (Klafs and Arnheim, 1985, p.251). In wheelchair sports, approximately half of the muscle strains occurred to the shoulders (44.6%), and 14.3% to the arms (Figure IV.7). The rationale for the high frequency of shoulder muscle strains was the great demand the biomechanics of wheelchair movement placed on the upper body musculature. The tremendous stress to the shoulder joint and surrounding musculature was a result of the combination of: the physiologically more strenous synchronous arm movement used in wheelchair propulsion, the biomechanically greater strength demands required of fulfilling all actions from the seated position, and the use of the same body parts to have carried out both daily activities and wheelchair sports skills.

The widespread occurrence of muscle strains was coupled with the equality of strains suffered by each shoulder. Muscle strains were sustained equally to the left and right shoulders. The synchronous arm action in wheelchair propulsion involved muscle action bilaterally. If the power of one arm was dominant, the wheelchair would have followed a crooked, energy wasteful path. Perhaps the equality of synchronous bilateral arm muscle contractions in wheelchair propulsion accounted for the injury pattern of bilateral shoulder muscle strains.

The numerous sports muscle strains occurred in, supported the prevalent scientifically based hypothesis that wheelchair sports were demanding for the upper body of wheelchair athletes (Glaser, [illegible]; Brattgard et al. 1970, p.148; Whiting et al. 1983). One third ([illegible]) of the muscle strains occurred in track events followed by [illegible] in basketball, [illegible] in [illegible], and [illegible] in [illegible]. The remaining [illegible] of muscle strains occurred in weight lifting.

Body Parts Injured
(n=56)



Sports The Injury Occurred In
(n=53)

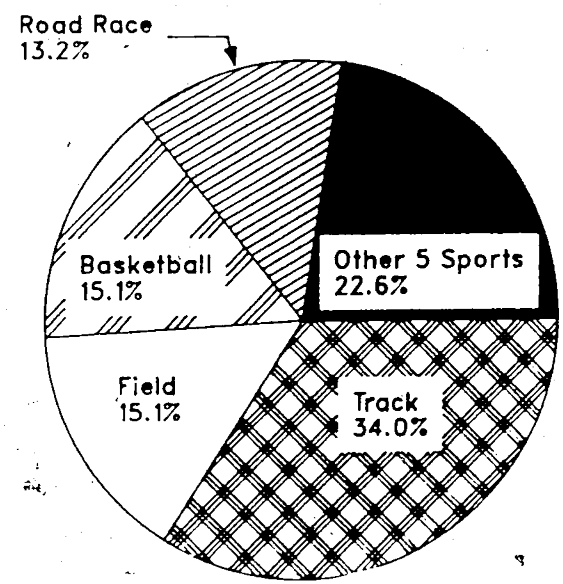


Figure IV.7 Muscle Strain

(7.5%), rugby (5.7%), swimming (3.8%), tennis (3.8%), and riflery (1.8%). Twenty percent (20%) or 11 of the 44 athletes with muscle strains, sustained strains in more than one sport (Figure IV.7).

Track events and road racing together accounted for nearly half (46.8%) of the muscle strains. These sports events relied on the fastest time achieved over the distance raced as the determining criteria for the finishers' rankings. Thus, both in training and competition road racers and track athletes, especially sprinters, pushed themselves to their maximum. To have achieved the speed necessary to overcome inertia at the start of a race, to have sped past an opponent in a race, or to have crossed the finish line just ahead of an opponent, were all situations which demanded forceful muscular contractions often coupled with excessive stretch (Crowe, Auxter and Pyfer, 1981). When these same muscle tissues were repetitively overstretched, the resultant chronic inflammation predisposed them to chronic muscle strain (Klafs and Arnheim, 1985, p.251).

Both road racing and rugby accounted for fewer muscle strains than field events. Close to 30% of all field event injuries were muscle strains (28.5%) (Appendix G:5). This high frequency of muscle strains in field events could have been directly related to the torsional stress and abnormal movement characteristics of this sports event. Naturally, wheelchair athletes competed in only the throwing events of shotput, discus, javelin (club throw for quadriplegics). These throwing field events were the same as able-bodied field events with the exclusion of hammer throw. Their limited or lack of function in the lower limbs of wheelchair athletes exempted them from the jumping events of pole vault, high jump, long jump and triple jump. The mechanism of throwing in field events, and shooting in basketball could have produced either overstretching or tortional stress to the soft tissues of the upper body. The focal point of the stress in throwing, passing, shooting was the shoulder joint. Also, the overhead or side arm motion used in field throwing events was an atypical movement. Few activities of daily living invoked the throwing action on a regular basis. In fact, the full shoulder function necessary throughout the javelin throw involved considerably more motion than that required for many daily activities (Matsen in Frankel and Nordin, 1980, p. 226).

To achieve full shoulder rotation in throwing, athletes must attempt to obtain the greatest external rotation possible at the shoulder joint. However, unlike able-bodied athletes, wheelchair athletes, cannot rotate their bodies simply by repositioning their feet. Rather wheelchair athletes, lacking lower limb function, must obtain maximum shoulder external rotation by placement of their upper bodies in a position of great torsion. For example, to throw a javelin or put a shot a long distance, the wheelchair athlete rotated at the trunk, supported themselves in their stationary wheelchair with their non-throwing arm, and maximally extended their throwing arm. This position allowed the arms to impart maximal force and velocity to the object. Without the use of the lower limbs, wheelchair athletes accomplished the wind-up phase, acceleration or release phase, and the follow-through of the throw with only their arms. The resultant microtrauma of this concentrated effort of the arms together with the repetition of the throwing action, strained the musculature of the shoulder complex.

Coupled with the great biomechanical stress of the throwing from a seated position without the use of the lower limbs, two other factors influence the occurrence of shoulder muscle strains in wheelchair field athletes. First the arm muscles may have been poorly warmed-up for the throwing action and second, quadriplegics often have temperature regulation disorders. Several researchers and specialists in sports injury prevention have advocated that

> in field events, sweat clothing should be worn for warm-up and replaced immediately following a competitive effort. If rather long periods of time elapse between trials or events, the performer should use light warm-up procedures during the intervals. Furthermore, on cool days, warm-up should be increased in duration

(Klafs and Arnheim, 1985, p.308) It has also been well researched that muscles that had been warmed-up prior to activity worked more efficiently, and that cold muscles predisposed a performer to injury. "Care must be taken to warm-up properly to prevent muscle tears or strains, and to raise muscle and deep body temperatures to their most effective level" (Klafs and Arnheim, 1985, p.118).

Unfortunately, the warm-up routines available to wheelchair athletes often involve wheeling. Seldom were the wheeling surfaces that were nearby field events suitable terrain for wheelchair travel, and if there was a track or suitable surface nearby, rarely was it available. Many track and field meets scheduled track events and field events simultaneously. Thus as the inner field was in use, athletes were racing on the surrounding track. As a result, not only did these athlete often lack the opportunity for an extensive warm-up, but they frequently endured long periods of waiting between class competition throws.

It is not uncommon for the high level spinal cord injured athlete or quadriplegic to have poor body temperature regulation (Appendix H). This interesting factor had significance with regards to the frequency of muscle strains in field athletes because four out of the eight or 50% of the muscle strained field athletes were quadriplegics. The lack of a functioning temperature regulation system in this class of athletes caused them to be extremely sensitive to slight alterations in wind or air temperature (Appendix H).

Similiar to wheelchair field events, wheelchair basketball involves throwing an object from the seated position. To score, the basketball has to follow the correct trajectory to the basket. Thus the basketball player is most concerned with the accuracy of the shot rather than distance alone. Unlike field throws, the basketball shot does not require the degree of torsional stress of the wheelchair athletes' upper body. In contrast, the occurrence of muscle strains in wheelchair basketball is influenced by the players' seated stature.

Although the rules for both the basket height and the basketball dimensions of circumference and weight are the same in able-bodied and wheelchair basketball, there is a drastic difference in player height. The wheelchair athlete's average sitting height is approximately two-thirds of the average human standing height. The lower height of wheelchair basketball players increases the distance the ball must travel to the basket. Higgs (1984) in a study comparing the set shot of wheelchair basketball players and stand up basketball players, found that wheelchair basketball players generated greater muscle torques in order to propel the ball towards the rim (Higger, 1984). Thus by altering only the height of the shooter, wheelchair basketball has become more demanding.

In able-bodied basketball players, the legs initiated the force of the shooting motion, transferred the weight to the shooting arm, and fully absorbed the deceleration forces. The powerful lower limbs were well suited to this transfer and absorption of great forces. Thus in the taller able-bodied athlete, not only did basketball shooting require less effort, but the lower limbs were an available source of power. In contrast, the wheelchair athlete had to generate enough force from the upper body to shoot the basketball a great distance to the basket. All phases of the shot were initiated and controlled by the upper body. The shoulder joint and surrounding muscles became the focal point of the muscle forces generated to shoot, pass, or dribble the basketball. Thus the arms and shoulders were predisposed to muscle strain in wheelchair basketball players.

In addition to the strain of the shoulders muscles which imparted the force to the basketball, basketball players spent a lot of game time on the floor. often the player spilled out of their wheelchair as a result of: colliding with another opponent, losing control, or loss of balance by, for example, an overzealous defensive play. Muscle strains may have occured when t[illegible]ete attempted to right themselves and their chair after a fall or to reg[illegible] they were tipping. The source of injury mechanism for muscle [illegible] largely from wheelchair spills. Whether the fall was caused by [illegible]eelchair, or from loss of balance, a fall in a congested race could [illegible] multiple wheelchair collisions led to more serious injuries such as [illegible]ons or concussions.

Approximately 60% of the 34 athletes in the sample population with greater than four years competitive experience, suffered muscle strains. Those athletes who had competed for two to four years, or less than two years, sustained muscle strains in less than 50% of the sample. Thus the relationship of muscle strains and competitive experience illustrated an equal distribution of about 50% of athletes who sustained strains regardless of their competitive sports experience.

(iv) Tendinitis

Both tendinitis and bursitis are overuse type injuries. An overuse injury is one which has occurred over time through repetitive movements of the same muscle group. It should be noted that the distinction between the terms tendinitis and bursitis may be more apparent than real. First, there is a differential diagnosis of similar injuries presented to different doctors and second, although these two inflammatory conditions are important diagnostic labels to a specialist, they may sound similar to the lay-person or athlete.

Only four body parts frequently sustained tendinitis injuries, compared to the 11 body parts which sustained muscle strains. These tendinitis injuries reportedly occurred to shoulders (48.3%), elbows (27.9%), wrists (20.7%) and thumbs (3.4%) (Figure IV-8). The high frequency of injury to these upper body parts was accounted for by the general stress imparted to the shoulder, wrist and thumb joints by the general characteristics of the wheelchair stroke. As mentioned there is tremendous stress to the smaller upper body muscles to wheel a wheelchair. Fifty percent of the athletes were occasionally plagued by tendinitis injuries to the shoulder, elbow and/or wrist, while tendinitis injuries occurred only once in 20% of the sample. The chance of tendinitis affecting both elbows or both shoulders was 40%. Tendinitis occurred most often in only one wrist (20%), and equally in both shoulders.

Wheelchair basketball players suffered 24% of all the tendinitis injuries in this survey, while track athletes topped them with nearly 30% (29.7%). The remaining tendinitis injuries (22.3%), were distributed over six different sports including rugby whose players suffered 5.4% (Figure IV.8). Ten (10) persons, or one third of the athletes with tendinitis injuries, sustained tendinitis in more than one sport.

In able-bodied sports, elbow tendinitis occurred primarily to athletes involved in racquet sports or throwing sports such as baseball (Klafs and Arnheim, 1985, p. 260). Furthermore, acute elbow tendinitis often became a chronic condition in athletes who

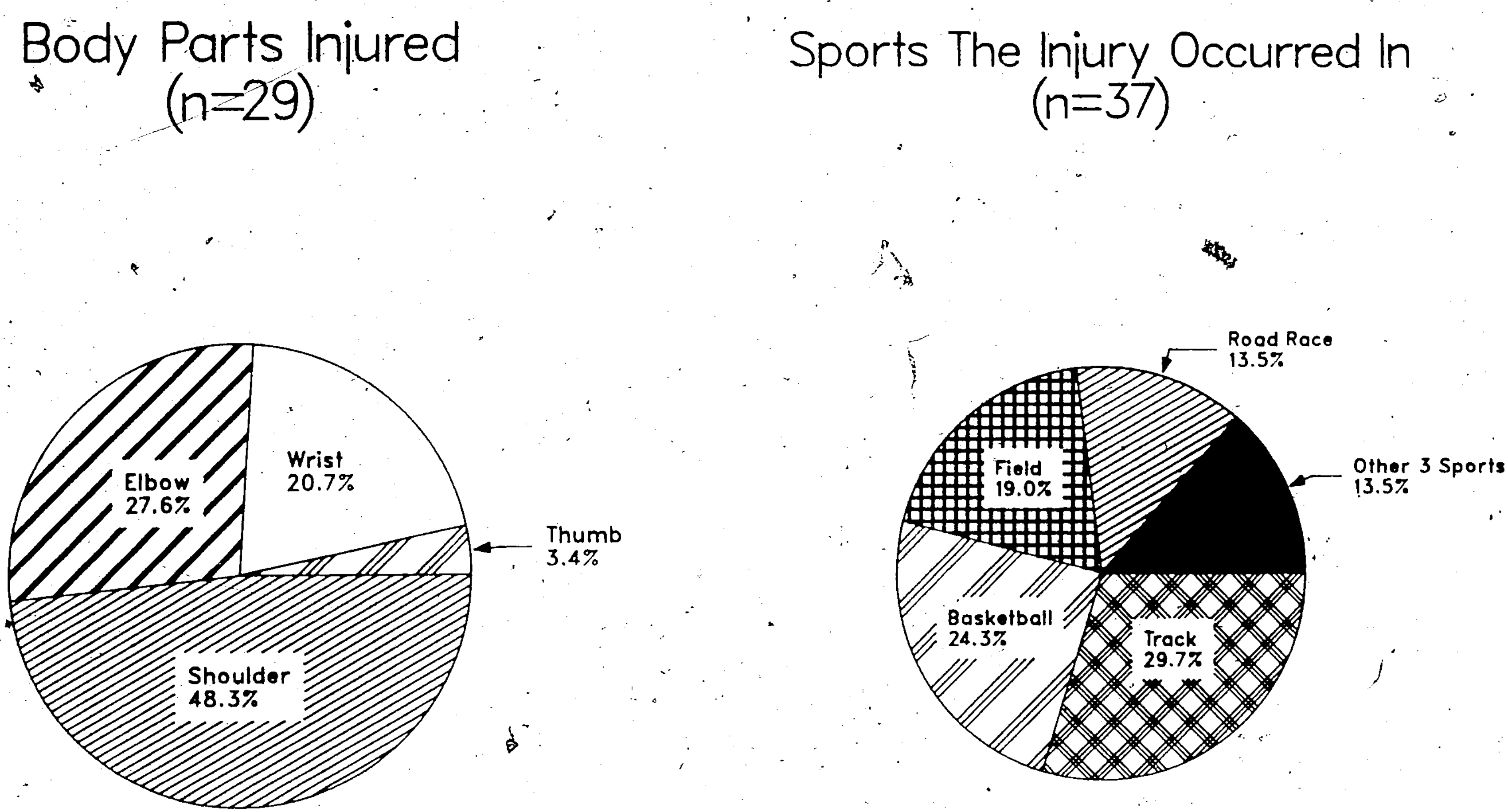


Figure IV.8 Tendinitis

repeatedly executed forearm pronation and supination movements. Such forearm rotation is common in tennis, javelin throwing, softball pitching, and the wheelchair stroke.

Severe stress in wheelchair athletes' joints was caused by the constant, repetitive and violent torsion and extension movements typical of wheelchair activities. One of the specific sources of tendinitis in wheelchair athletes was poor technique. Their technique is influenced by both their body positioning prior to the execution of a skill, and the amount of weight transferred. Lacking movement control of their lower limbs, the upper body of wheelchair athletes had to serve both as the power source for movement, and as the initial link of the kinetic chain of motion.

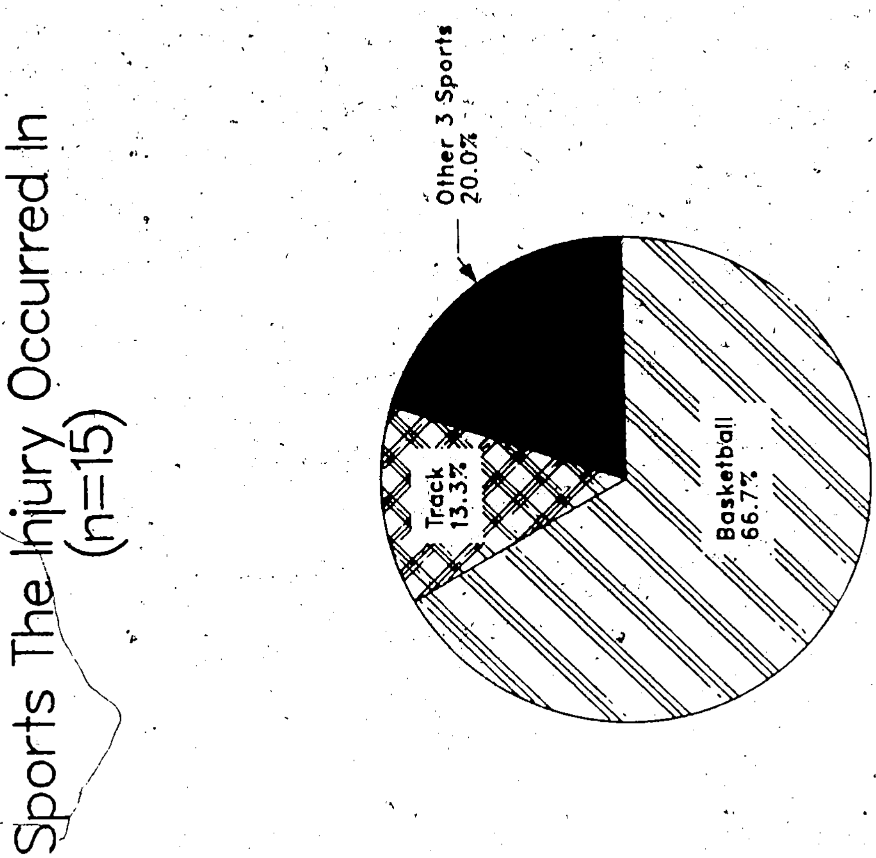
The upper body is a comparably weak power source because it lacks the muscle size and bony leverage of the legs. The biomechanically correct positioning of the arm and shoulder in a wheelchair, prior to the release of an object in throwing, prior to the striking of a ball in racquet sports, or prior to the release of the basketball is difficult to obtain without the ability to influence the upper body position by adjusting the lower body. As a result, wheelchair athletes who used poor technique in practicing or performing their sport skills increased the stress to their elbow joints. The wheelchair propulsion stroke perhaps was the major source of shoulder tendinitis while poor technique was possibly the most common cause for elbow tendinitis in wheelchair sports especially racquet sports, throwing events, and shooting.

The kinetic link for wheelchair propulsion begins with the shoulder and ends with the thumb imparting energy and absorbing energy from the wheelchair hand rim. More specifically, thumb tendinitis or tenosynovitis (inflammation of the sheath surrounding a tendon) commonly occurs in sports which require a great deal of wrist action (Klafs and Arnheim, 1985, p.756). The thumb and wrist followed a circular path on the wheelchair hand rims. The irritation the wrist joint and thumb were subjected to in wheeling may have become so severe that chronic inflammation resulted.

(v) Muscle Bruises

A muscle bruise or contusion is a soft tissue injury inflicted upon the skin and underlying musculature by an outside force. In wheelchair sports muscle bruising occurred frequently to participants in basketball (66.7%), track (13.3%), and three other sports: road race (6.7%), rugby (6.7%), and racquetball (6.7%). Eight body parts sustained muscle bruising: arms (29.5%), shoulders (17.6%), and legs (17.6%) (Figure IV.9). It was alarming that such a high percentage of legs were bruised in wheelchair sports; activities in which the athletes used their upper bodies for movement and skill execution. However, the popularity of wheelchair basketball may have accounted for this statistic. Throughout basketball games, the players, either through loss of balance, or collisions with their opponents, fell onto the floor. Many of these players used straps to keep their legs onto their wheelchair foot rests, thus when they fell, the wheelchair and the athlete landed together as a unit. The legs were often the first body part of the 'unit' to make contact with the floor.

There were substantially fewer muscle bruises recorded by track athletes possibly because track is a non-contact individual sport. Although there are track team events, there is not defensive tactics which involve collisions within the game plan of track athletes. The spills that did occur in track were possibly caused by mechanical failure of the wheelchair, flat tires, or forcing another competitor off the track at the curve. Flat tires were caused from debris such as sharp glass, rocks, or metal objects left on the race course surface. Although bicyclists also race on pneumatic tires, they may have avoided debris on a race course because they were capable of swiftly turning their wheels sideways. It was unlikely that wheelchair athletes were able to avoid the debris because not only were they moving quickly, but they were not able to manoeuveur their wheelchairs sideways. Attempts by athletes to avoid interference in their path of travel by quickly swerving their wheelchairs to alter their course were often disastrous. In trying to regain their balance from having tipped onto one wheel, wheelchair track athletes who fell would likely have begun a multiple collision. Wheelchair athletes who fell or were involved in a race collision and suffered muscle bruises, probably considered



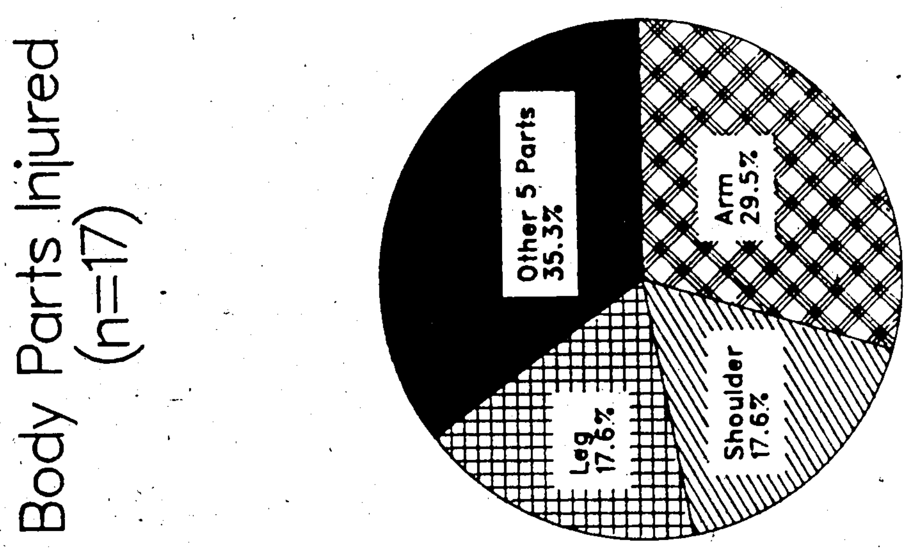


Figure IV.9 Muscle Bruise

themselves lucky to have wheeled away without more serious injuries.

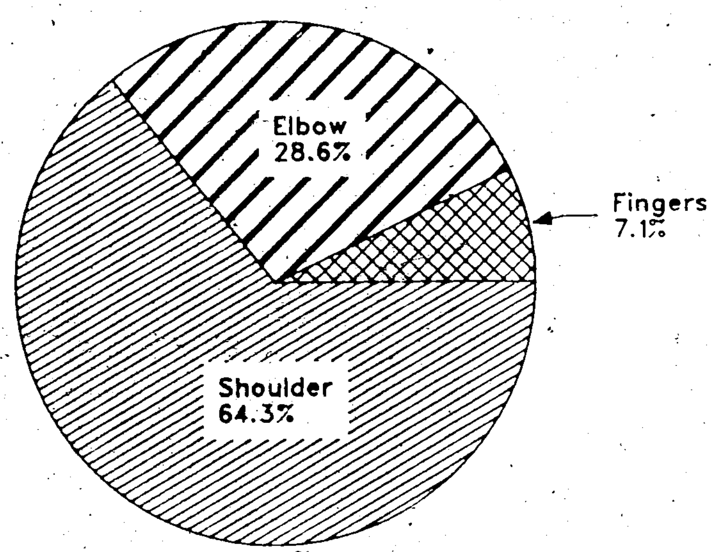
(vi) Bursitis

Bursitis, the other overuse injury reported by the wheelchair athletes, occurred less frequently (4.8%) than tendinitis. Similiar to tendinitis, bursitis injuries most frequently occurred to few body parts. The shoulders (64.3%) accounted for almost two-thirds of all bursitis injuries, while the remaining one third of bursitis injuries reported, occurred to the elbows (28.6%), and the fingers (7.1%) (Figure IV.10).

The bursae in the hand surround the tendons and therefore are known as tubular bursae or synovial sheaths (Basmajian, 1976, p.120). Thus finger bursitis is commonly referred to as a synovitis or inflammation of the synovial sheath. The hand grip in wheelchair propulsion involved contact with the hand rim made primarily by the index finger and thumb. Although several athletes, especially road racers, reinforced their gloves with tape, the wheels' constant irritation led to local inflammation. The continual finger joint inflammation led to chronic strain. The wheelchair racers who generously reinforced their gloves concentrated on thickening the tape layers surrounding the thumbs and the index fingers (Plate IV.1). These athletes taped their joints in the position comfortable for wheeling. This position was possibly very close to the natural relaxed angle of the joints in the hand.

In the technique used by racers except quadriplegics, the taping limited the available range of motion at the distal interphalangeal (DIP) and proximal interphalangeal (PIP) joints of the index finger, and the DIP joint of the thumb. Although little was mentioned of the forces these joints were normally subjected to in wheelchair propulsion studies, perhaps taping altered the pattern of energy absorption. Perhaps the brunt of the forces of wheelchair road racers' tape-reinforced gloved index fingers and thumbs were concentrated at the MCP joint. Further medical studies which discuss the distribution and absorption of forces in the fingers and hand of wheelchair road racers are needed to verify this hypothesis of glove-induced force concentration at the MCP joint in the fingers of these athletes.

Body Parts Injured
(n=14)



Sports The Injury Occurred In
(n=17)

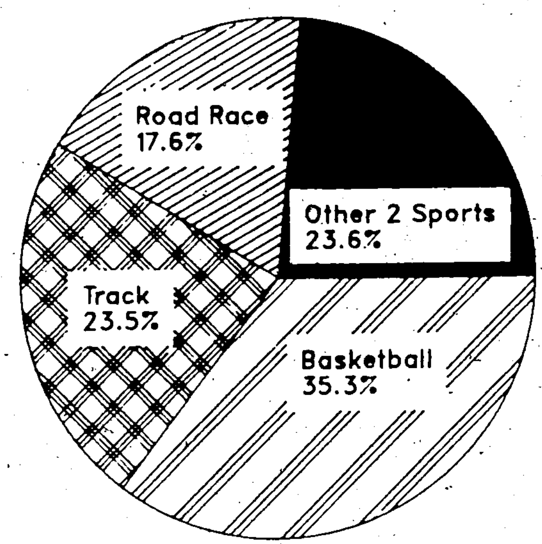


Figure IV.10 Bursitis

The many bursae around the shoulder joint are easily subjected to traumatization by the deltoid muscle. This relatively superficial muscle defines the shoulder cap. The anterior deltoid muscle together with the pectoralis, triceps and wrist musculature transferred force to the wheelchair push rims to initiate the wheelchair stroke (Byrnes, 1983, p. 55). As the deltoid muscle contracted during wheelchair propulsion, the deeply seated subdeltoid bursa may have been forced against the bony acromial shelf (Klafs and Arnheim, 1985, p.260). Subsequently, the posterior portion of this deltoid muscle contracted during the recovery phase of the wheelchair stroke (Byrnes, 1983, p. 55). The underlying bursa, irritated by the deltoid muscle over-produced synovial fluid. Once this fluid increases within the bursa sac, the process leading to bursitis is self-perpetuating. The increased amount of fluid leads to more tension within the sac, and increased tension from the overlying tendons. In able-bodied sports, shoulder bursitis is a direct result of overuse in more than 95% of shoulder irritation (Southmayd, 1981, p. 120). 'Wheelies' frequently use their arms for prolonged periods to propel their wheelchairs during both sports and daily activities (Emmes, 1977). This repititious shoulder movement could be a source of shoulder irritation, and thus would account for the high frequency of wheelchair athletes with shoulder bursitis (McCormack, 1984, p.19).

Elbow bursitis in wheelchair athletes is a result of traumatization of the olecranon bursa by direct blows, or falls or projecting objects (Klafs and Arnheim, 1985, p.710). The elbow bursa was frequently injured in wheelchair sports because its' superficial location made it prone to injury.

Basketball (35.3%), track (23.5%), road race (17.6%), field (11.8%), rugby (5.9%), and weight lifting (5.9%) were the sports in which bursitis injuries occurred (Figure IV.11). Bursitis injuries accounted for seven percent (7%) of all the injuries reported in field events or in road racing (Appendix G:3). The throwing action of field events placed maximum stress upon the elbow and the shoulder (Cabrera and McCue, 1986, p.681). In the seated posture, the use of the legs to transfer weight and momentum is eliminated. The upper body must initiate the forces to culminate in a throw, and absorb the energy at the release of the object. In addition to the demands associated with throwing while seated, disabled athletes may lack complete innervation of forearm musculature. An imbalance of antagonist and agonist muscle movers surrounding any joint can readily become a weak link. Continued development through constant use of either wrist flexors or extensors could result in irritation at the elbow joint flexor/ extensor insertions. Swelling, or continued irritation to the elbow joint severely curtails wheelchair athletes' mobility. Although bursitis is primarily an overuse injury, acute bursitis of the elbow occurs. The vulnerability of the bony olecranon prominence and its underlying protective bursa to injury from falls or collsions is great. The subsequent swelling to the elbow joint limits the complete range of movement at the elbow. To prevent elbow joint irritation, and subsequent inflammation, resulting from continued wheelchair propulsion, daily exercises for flexibility and balanced strengthening should become habit. In other sports, where collision injuries are common, protective padding should be worn around the elbow joint. Attention to good technique, a moderate degree of wheel camber, variable training terrain, and pre-activity warm-up and stretching is important for the prevention of upper limb injuries which often threaten to curtail elite wheelchair athletes' careers.

Rare Injuries in Wheelchair Sports

The most rare types of injuries were: eye injuries (1.4%), dental injuries (1.4%), and dislocations (0.7%). The first two injuries were reported within the larger category of 'head and face'(6.3%)(Figure IV.3). Eye injuries to able-bodied athletes result from damage inflicted by missiles such as squash balls, tennis balls, or racquetballs travelling at high speeds (Easterbrook, 1987, p.180). It was doubtful whether the high speeds of ball travel, generated by the forceful swings characteristic of able-bodied racquet sports' players, were equalled by wheelchair racquet sports' players. Such great forces imparted to a ball in able-bodied racquet sports equalled speeds of 110mph in the advanced level tennis players or 85-110mph in the intermediate level racquetball player (Easterbrook, 1987, p.180). Possibly the biomechanical disadvantage of swinging a lever or racquet while seated is so great that, the resultant force imparted to the object or ball is small. Perhaps less serious eye injuries would result from missiles travelling at reduced velocities. These conjectures have not yet been verified because equivalent measures of the ball speeds generated in wheelchair racquet sports have not been reported in the literature.

In addition to the less damaging, slow travelling missiles in wheelchair sports, dental injuries and eye injuries are perhaps less common because of the head position of these athletes. In able-bodied sports the head is often intentionally at the ground level or, equal to, or below the level of the lower limbs. For example volleyball dives, squash saves, ice hockey defensive dives, and curling are all sports where the athletes horizontal body position dictates a [illegible]sition level with the lower limbs. In wheelchair sports the athlete remains in a seated p[illegible]n. Their head is seldom intentionally below their seated center of gravity. The wheelchair athletes' position their heads so they are up and facing forward, primarily to keep their balance, but partly because of the mechanical properties of wheelchair motion.

Typically, the athletes must direct their wheelchairs to face their intended direction of travel because the wheels on a wheelchair allow only forward or backward movement. Thus, when moving in a wheelchair the athletes' heads are always in line with the rest of their body. Since a sideways movement (moving sideways while facing forward) is impossible in a wheelchair, only the most skilled wheelchair athletes can fake a movement in one direction and travel in another. Based on this observation, wheelchair athletes travel, almost exclusively, in the direction they are looking. The low number of teeth and eyes reportedly injured was perhaps related to the protection of their face by their forward-facing seated position. This semi-erect position made face contact with the floor an accident, caused only through collision and loss of balance. In wheelchair sports, facial injury caused in the course of an intentional movement by the athlete was unlikely.

The most rare injury reported in wheelchair sports was dislocations (0.7%). The injury mechanism of dislocations is characterized by a great force on the structures within a joint, causing the joint to go beyond its normal anatomical limits (Klafs and Arnheim, 1985, p.252). In able-bodied sports the highest incidence of dislocations involved the fingers and the shoulders (Klafs and Arnheim, 1985, p.252. The two dislocations reported in wheelchair sports occurred to the elbow and fingers in the sports of basketball and wheelchair rugby. Perhaps athletes in wheelchair track events and several other sports avoided dislocation injuries because they were well practiced in properly utilizing their arms to break their fall from their wheelchairs. The low frequency of dislocations in basketball and rugby was perhaps related to the distance the wheelchair athlete is from the ground. The seated position of the wheelchair athlete lessened the falling distance to the playing surface. Competition in a wheelchair also eliminated the endless possibilities of injury inflicted upon able-bodied athletes by the speed and rotational torques created by lower limb movements. Lacking the functional power of the lower limbs, these athletes are seldom involved in sports which require them to land on upper body parts. For example, wheelchair athletes would not be tumbling on a mat, throwing an opponent in a wrestling match, or being tackled to the ground in a soccer game.

Many of the able-bodied shoulder joint injuries, especially dislocations, are caused by landing on the point of the shoulder, falling on an outstretched arm, or downward forces directed at the shoulder joint. The descending forces of this latter cause of shoulder dislocations drive the acromion of the shoulder downward and away from the clavicle, a shoulder bone which sustains the acromion's position. (Klafs and Arnheim, 1985, p.706). Yet, it is unlikely whether wheelchair athletes would fall on the point of their shoulders in sports or whether the forces generated through wheelchair sports participation are of the magnitude to disrupt the joint structures. Thus it was reasonable that in wheelchair sports, dislocations were the most rare type of injury reported.

When the wrist is chronically inflammed, essential vessels and the median nerve cannot pass freely through the wrist's carpal tunnel. The resultant numbness and pain radiating from the thumb, wrist, and hand have been termed carpal tunnel syndrome (CTS). Although no athlete in this study specifically reported the occurrence of CTS, inflammation injuries to the wrists (16.5%), hands (16.5%), thumbs (12.3%), and fingers (12.3%) were reported. Inflammatory injuries to these four body parts accounted for more than half of the total frequency of inflammatory injuries (6.7%).

Two factors contributed to the absence of reported CTS amongst wheelchair athletes. First, was that the signs and symptoms of CTS may have been confused with the characteristic signs and symptoms of high cervical lesions in quadriplegics. This disability class have altered muscle innervation to the arms which is often accompanied by altered sensation to the arms and hand. Specifically, pressure on the spinal cord in the cervical spine region presents as numbness and tingling in the thumb and next two fingers, and pain in the wrist which occasionally radiates up the forearm, upper arm, or even to the shoulder (Austin, 1972, p.368). This numbness and pain pattern simulates the common symptoms of CTS which perhaps, to the quadriplegic athlete was interpreted as ordinary signs and symptoms of quadriplegia.

The second factor was that CTS requires a doctor's diagnosis as did bursitis, tendinitis, fractures and other injury types. Wheelchair athletes with signs and symptoms of wrist, hand, or thumb inflammation were perhaps unlikely to have been alarmed by these symptoms. Perhaps medical attention was not sought. Thus although CTS may have occurred in wheelchair athletics, its frequency in this study, especially amongst quadriplegic athletes, remained unknown.

Serious Injuries in Wheelchair Sports

a) Concussions

Seven athletes sustained concussions to the head or forehead/eye region in four different sports events. Almost half of all of the concussions (42.8%) were sustained by quadriplegic rugby players. The remaining sports in which concussion were reported included: track events(28.6%), basketball (14.3%), and slalom (14.3%) (Figure IV.12). Six of the seven

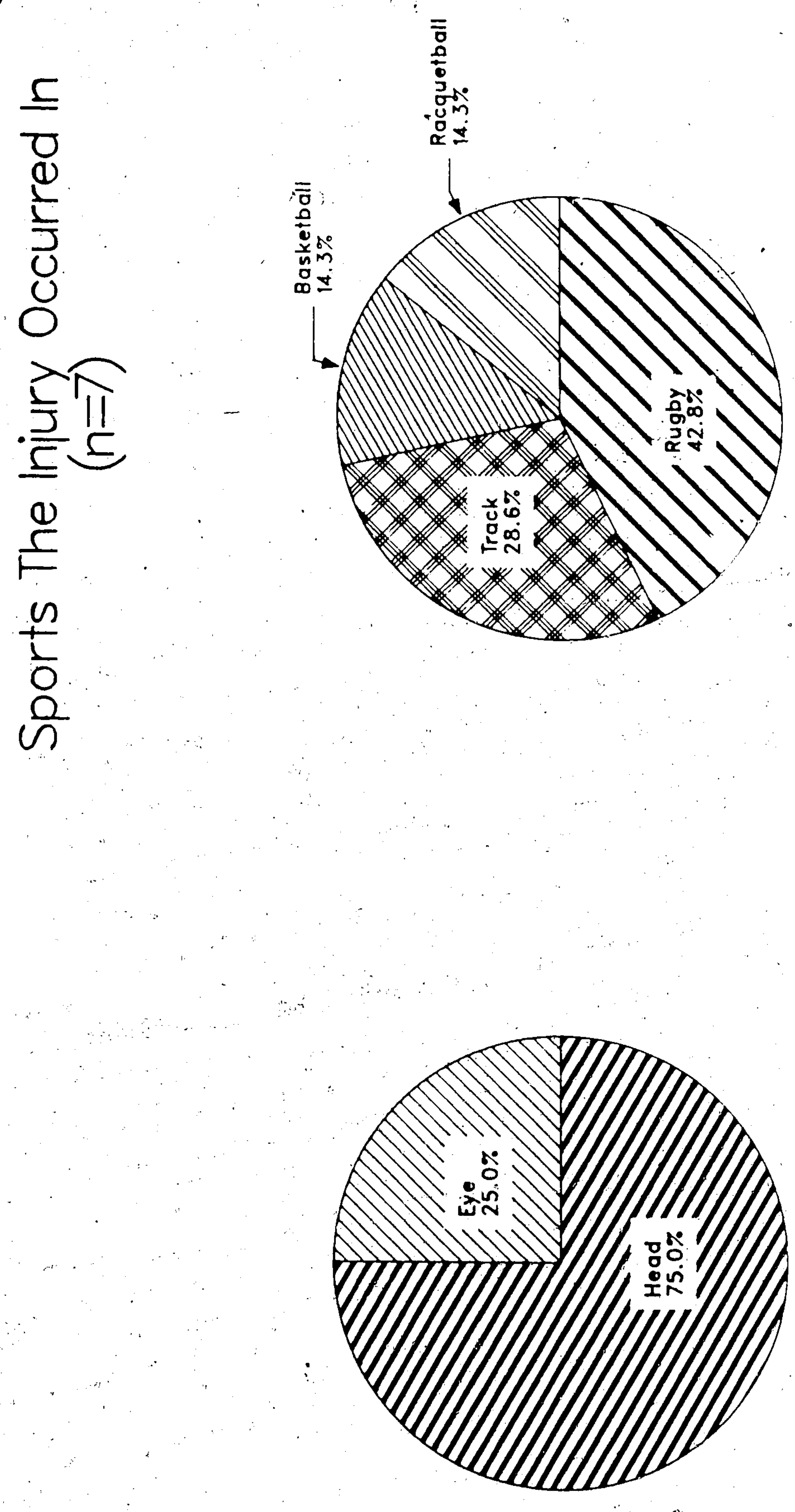


Figure IV.11 Concussion

concussions occurred to quadriplegics.

The high frequency of concussions in wheelchair rugby was probably directly related to the functional characteristics of quadriplegics. Lacking trunk musculature or useful hand intrinsic muscles, balance is a problem for the high level spinal cord injured athlete. This anatomical lack of innervated postural musculature together with the defensive plays in whewelchair rugby, made the head more vulnerable in the quadriplegic class of athletes. Unlike many amputees, 'les autres', and amputees, quadriplegic athletes have limited use of their arms and hands. Unable to use their arms to break their fall, or to grip firmly onto their chairs with their hands, made the heads of quadriplegics more vulnerable to injury. If quadriplegic athletes lose their balance and begin to tip out of their wheechairs, most lack the abdominal or trunk musculature to keep themselves in their chair, let alone right themselves.

The final factor predisposing quadriplegics to concussions through sports participation was that many of these athletes strapped their legs to their wheelchairs. The legs are strapped to their wheelchairs both to prevent them from falling off and subsequently suffering injury under the wheelchair, and to assist in controlling involuntary leg extension. The first factor is characteristic of the spinal cord injured athlete with a lower motor neuron lesion which results in flaccid paralysis below their lesion level. Their legs tend to be very influenced by gravity and often fall off the wheelchair foot rest. The dragging of the feet is a source of injury from contact with the playing surface, their wheelchair, or others' wheelchairs. The second factor is characteristic of the spinal cord injured athlete with an upper motor lesion with resultant spastic paralysis below their lesion level. When involuntary muscle tonus sets in, the legs immediately extend at the knee. This complete, immediate and rigid leg spasm alters the center of gravity, and makes the legs a physical barrier vulnerable to injury. The legs strapped to the wheelchair are useful in moderating the injury vulnerability of the legs, however it also joins the wheelchair athlete and wheelchair as a single unit. This unit moves together and falls together. Thus when these quadriplegic athletes who have their legs strapped to their wheelchairs collide, extend themselves in a defensive or offensive play, or lose their balance, they cannot break their fall with their hands, rarely fall free from their wheelchairs, and therefore often concuss themselves when they fall backwards from their wheelchairs.

b) Fractures

Fractures (7.8%) occurred as frequently as concussions. Five different body parts were fractured in three sports events. Four (57.1%), of the fractures occurred in basketball while road racers (28.6%) and a tennis player (14.3%) accounted for the other fractures.

Expectedly, fingers were most commonly fractured in basketball or road races. Several factors provided an explanation for the high frequency of fractures in basketball. Basketball is a contact sport in which, although the playing surface is limited, the agility and speed of the athletes is great. The intensity of the offensive and defensive tactical plays in basketball together with the players' skills led to frequent wheelchair collisions which occasionally resulted in fractures (2.4%). There were a few ankle and foot fractures reported. These lower body fractures occurred in road racing and basketball. Many of the road race wheelchair design's positioned the body in a hyperflexed posture which left the legs dangling and the unprotected feet predisposed to injury. Seldom did road racers wear shoes, thus, if they fell or their legs became untied from their front caster and their wheelchair overturned, their feet would be subjected to injury.

Fractures are commonly caused by direct violence, indirect trauma, or sudden muscular contraction. Forces are generated by distance over time, therefore the speed gained by wheelchair road racers, basketball players or even tennis players would perhaps generate suffic[illegible] forces to cause violent bone damage. The athletes' foot position in many sports wheelchair's was well in front of the rest of their body. Thus in a forward collision or fall, the feet made the first contact with the other wheelchair or the ground. The combination of the lack of footwear worn, the high speeds at contact, and perhaps the lack of protective musculature surrounding the lower limbs of many wheelchair athletes were the situational factors which predisposed t[illegible] wheelchair athlete to foot and ankle fractures. It would seem that none of these factors alone would have generated enough force to damage bone, but foot fractures could have occurred from spills at the high speeds frequently travelled by road racers, or from direct contact collisions characteristic of basketball.

c) Pressure Sores

More pressure sores (9.0%) than concussions (7.8%) or fractures (7.8%) were reported by the sample population of wheelchair athletes. Out of these three (3) more serious injuries, Bedbrook (1985) stated that from a medical standpoint "pressure sores still remain one of the major complications of spinal cord injury" (Bedbrook, 1985, p. 73). In fact, multiple pressure sores with the involvement of bone and joint can be the cause of death in less than six weeks if they are unattended (Burke & Murray, 1975, p. 82). Pressure sores were sustained by one amputee and six spinal cord injured athletes in track (44.4%), basketball (44.4%), and field events (14.2%).

The possible causes of pressure sores throughout all sports events were: wheelchair design, length of activity, and rough edges, or objects of the wheelchair or wheelchair parts. The revolutionary designs of wheelchair sports chairs emphasized speed, lightness, and maneuverability. Especially in the aerodynamic designs of road racing or track wheelchairs, little effort or emphasis was given to the athlete's comfort. To fit in the bucket type seat design of these racing wheelchairs, the track athletes legs were fully flexed at both the hips and the knees. This position eliminated the dispersion of forces through the long bones of the wheelchair athletes' upper thigh. For example, seated on a chair or in a wheelchair basketball player's wheelchair, the hips and knees are flexed only to 90 degrees, and the long bones of the upper thigh were therefore able to have absorbed some of the forces of their body weight. Conversely, the 'bunched' leg posture characteristic of track athletes and road racers, placed the pressure of these athletes' body weight on three contact points: the two ischial tuberosities, and the back.

The lower frequency of pressure sores in field events was likely influenced by the shorter duration of field events. According to Burke and Murray (1975) there is a direct relationship between the amount of pressure and the length of time the body is subjected to the pressure. The body endures a small amount of pressure for an extended time period but sores were likely to have developed if a great deal of pressure was exerted over a small area for greater than two hours (Burke & Murray, 1975, p. 58). Basketball games, including warm-up and intermission, and the distance track events were probably longer in duration than field events. However, it was likely that the wheelchair seat surface was also an influential factor in the development of pressure sores. According to Richarson and Meyer (1981) quadriplegics are more prone to develop pressure sores than paraplegics (Richardson & Meyer, 1981, p. 237). However, in this study, an amputee and low level spinal cord injured athletes incurred the pressure sores. Perhaps many of these athletes were accustomed to ambulating with the aid of braces, crutch(es), or cane(s). Unaccustomed to the wheelchair, except for sports events participation and competition, perhaps these athletes did not have appropriate wheelchair padding or perhaps were less diligent in pressure sore preventitive care.

A pressure sore begins as a redness, or skin discoloration which advances to damaged tissue and superficial circulation if the pressure remains. Continued pressure further destroys deeper skin layers and eventually leads to necrosis, ulceration, and even local gangrene (Burke & Murray, 1975, p. 57). Athletes with altered sensation are perhaps predisposed to pressure sore development not because of any differences in their skin composition, but rather because they lack the warning mechanism to notify their bodies of the discomfort sensation of building pressure. Deprived of this sensory warning mechanism, these athletes must: actively develop a good hygeine practice, ritually relieve sitting pressure for a short time at least twice an hour, and daily inspect their bodies for early signs of pressure sores (Burke & Murray, 1975, p. 59).

Overall, the most common sites for pressure sores in wheelchair users are over the ischial tuberosities, the lower back where the back upholstery is in contact with the body, and the back of the thigh. The denervated areas of the body, especially those with complete sensory loss are most susceptible to pressure sores. The incidence of pressure sores is increased by inappropriate cushioning, improper wheelchair fit, and wrinkled clothing, and is relatively low among athletes. This study reported three body parts which sustained pressure sores: the pelvis and hip (57.1%), thoracic spine (28.6%), and chest (14.3%). All three body parts were, as noted, contact points between the athletes body's bony prominences and their sports wheelchairs. The ischial tuberosities of the pelvic region made contact with the bottom of the wheelchair seat. Thus on these two bony prominences alone, rested nearly the entire body weight of the wheelchair athlete. Minnis et al (1984) noted that the trunk posture and the leg position of the wheelchair athlete influenced the ischial tuberosity pressure pattern (Minnis et al, 1984, p. 298). They made a noteworthy contribution to the control of pressure sore development in wheelchair athletes with their use of an ischiobarograph device. They used this device to take measurements of peak pressure points in the ischial areas. They then modified the detected peak pressure points with cushions (Minnis et al, 1984, p. 304).

Pressure sores also developed over the thoracic spine or chest, perhaps at the level where the top of the wheelchair's seat contacted the athlete's back. The often firm, uncushioned top of the wheelchair seat was the contact point which partially shared the pressure of the athletes' body weight. Nilsen et al (1985) reported that "pressure sores...do not necessarily relate to physical training" (Nilsen et al, 1985, p. 157). Perhaps these pressure sores were not sustained as a result of wheelchair athletic competition or training but occurred during the course of the Games. Many of these competitions or Games were held over a few days. Relaxation tents or areas where refreshments and music were provided, were set up at the sporting venues. The atmosphere perhaps encouraged dancing when the athletes were not competing. To dance in a wheelchair to the beat of the music is often accomplished by maintaining a wheelie for the duration of the dance. Perhaps, it was the greater pressure concentration of the athlete's body weight over the thoracic spine in a wheelie, that caused the development of chest and thoracic spine pressure sores.

D. Injury by Disability

Spinal cord injured athletes had the greatest percentage (69.6%) of the total number of injuries by disability followed by 'les autres' (16.8%) and amputees (13.6%). However, this statistic reflects the percentage distribution of each disability group in the sample population (Figure III.1). Therefore the injury rate by disability was calculated from the total injuries by disability (n=339) and the total number of athletes in each disability group. This rate gives a more accurate indication of disability type and injury. The injury rate for the 'les autres' (4.07) was highest followed by the amputees (3.83) and then the spinal cord injured (3.68).

Perhaps the 'les autres' disability group had the greatest injury rate because of their disability characteristics. Many of the 'les autres' group lack coordinated movements and fine motor control. Their uncontrolled body movements could have been a factor in the injuries that they sustained. The most frequent injuries to 'les autres' were blisters (28.1%), abrasions (22.8%), and muscle strains (15.8%). Although there were no concussions or pressure sores reported, 'les autres' sustained a variety of serious injuries: fractures (5.2%), dislocations (1.8%), eye injuries (1.8%) and dental injuries (1.8%). Their ability to shift their body positions frequently accounted for the absence of pressure sores. However, the high percentage of blisters and abrasions to this disability group was perhaps because many of these athletes were unacustomed to daily wheelchair use. Many 'les autres' use alternate forms of locomotive aids when they are not competing in wheelchair sports.

The amputee disability group also reported an overall high injury rate (3.83). Similar to 'les autres', many amputees rarely use a wheelchair for daily locomotion. They are often able to walk with the use of protheses and/or alternate forms of locomotive aids. Although this group also reported a high frequency of blisters (28.3%) and abrasions(23.9%), muscle strains (13.0%), concussions (2.2%), and eye injuries (2.2%) were also reported.

Amputees who participate in wheelchair sports have missing lower limb(s) which change the body's center of gravity. The altered center of gravity affects the athletes' balance.

This changed center of gravity and altered balance results in a high frequency of spills or falls. The type of injuries sustained in falling may be serious for this disability group because of the great speeds involved. Amputees have full sensation, strength, and motor control of their remaining limbs. They are therefore agile and capable of many skilled movements and controlled sudden starts and stops. The control of their upper body movement is possible because of the fully innervated musculature of the thorax, abdomen, and back.

In contrast, the spinal cord injured disability group, who reported the lowest injury rate (3.68), did not have fully innervated postural muscles, lower body muscles, or some upper body antagonists. Furthermore, this disability group lacks full sensation of their paralyzed body parts. It has been suggested (Steadward, 1987) that because spinal cord injured athletes have some degree of paralysis, injury detection may be delayed. In some cases, visual physical signs and symptoms appear before a spinal cord injured athlete has detected an injury. For example, internal derangement of bone may go undetected in many spinal cord injured if the injury occurred to a paralyzed body part. Thankfully, the signs of inflammation, discolouration or fever may appear which lead the injured athlete to seek medical attention. Spinal cord injured athletes reported a high frequency of both blisters (22.9%) and abrasions (22.0%). They were the disability class with the highest incidence rate for concussions (2.5%), pressure sores (3.0%), muscle bruises (5.5%), tendinitis (12.3%), and muscle strains (16.1%).

E. Wheelchairs

In sports such as harness racing, motorcross racing, or skateboarding, the vehicle could become the source or mechanism of injury. Just as humans trip, fall, or pull a muscle during a competition, these vehicles can alter an athletes' performance through mechanical failure. Wheelchair sports are not exempt from the possible injuries caused through the mechanical failure of the wheelchair or its parts. For example, a loose bolt, a fold or crease in chair upholstery, or a tire blow-out, could cause an injury as slight as an abrasion or as serious/complicated as a fracture or a pressure sore.

The wheelchair as a vehicle extends the upper limit of man's fastest speed. On short downhill sections of hilly marathons or road races, wheelchair athletes have reached speeds in excess of 40 mph (Vince, Ierretti, 1986). In sports where such excessive speeds are attained, the resultant injuries that occured were more seriou.. The direct relationship of speed and impact forces is such that the chance of injury also increased. Thus based on both the high frequency of soft tissue injuries reported in this study, and the great speeds attained in many wheelchair sports, protective equipment should be worn.

Many able-bodied and disabled athletes use protective sports equipment to protect themselves from injury, and to protect an injury from further trauma (Roy & Irwin, 1983, p. 45). This study's statistics revealed that a remarkably high percentage of wheelchair athletes (72%) wore protective gear while training, participating, or competing in wheelchair sports. There were eight different types of protective gear used: gloves, leg straps, arm bands, sport glasses, tape, cushions, knee pads, and helmets. More than one third (37.5%), of the athletes who wore protective gear used more than one type of gear. It was interesting that the most frequent combination of protective gear was gloves and leg straps. The quadriplegics were the disability group who most commonly (58.3%) used both gloves and leg straps in wheelchair sports. Perhaps, as already suggested, the use of the leg straps was related to their disability characteristics, whilst the high frequency of gloves worn would suggest that perhaps these athletes wore gloves in many sports such as sledge hockey, sit-skiing, rugby, archery, track, and road racing.

Gloves were worn by 60% of all the wheelchair athletes who wore protective equipment, while 23.3% wore leg straps, and 8.9% wore arm bands. Three athletes wore sports glasses, and only one athlete, while kayaking, used a helmet. The gloves served as protection to the hands against blisters and abrasions. Often the first two fingers and the thumb were reinforced with layered white adhesive tape. The glove material varied in its ability to withstand the frictional stresses associated with wheelchair sports (Plate IV.1). Some athletes have found that deer skin curling gloves were the most resistive to the wear and tear of wheeling (Hansen and Taylor, 1987).

All the legs straps reported in the study were used by spinal cord injured athletes. As mentioned, the wheelchair athlete with spastic paralysis would have used leg straps to control involuntary leg movement while the wheelchair athlete with flaccid paralysis below their lesion level would have used leg straps to keep their legs positioned on their wheelchair. No amputees or les autres in this study used leg straps.

Greater than 75% of the athletes involved in road racing (77.8%), archery (80.9%), track (81.8%), and bowling (83.3%) wore protective gear. All outrigger skiers, sit-skiers, and sledge hockey players and 96.4% of rugby players also wore protective equipment. Perhaps some form of equipment should be designed to prevent injuries to wheelchair basketball players. The greatest number of injuries were reported in wheelchair basketball, and less than two-thirds (62.5%) of these athletes wore any type of protective gear.

This study illustrated that although many wheelchair athletes wear protective gear, the type of equipment most commonly worn was designed to protect the hands. However, the high frequency of blisters and abrasions that reportedly were sustained by the hands, suggests that the gloves were not effective in their protection. Perhaps the discovery of a more resilient glove material which still conforms to the hand, would effectively eliminate blisters and most abrasions from wheelchair sports.

Arm bands possibly served as a preventitive measure in the development of arm abrasions while wheeling in a cambered track or road racing wheelchair. As explained, the cambered wheels contacted the inside of the arms and the chest wall. On hot race days, a shirt might have provided the necessary layer of protection to the chest wall, but only a long-sleeved shirt would have covered the arms. Furthermore, since the arms were the primary moving appendage in wheeling, perhaps the shirt worn was not thick enough. On hot days a thicker shirt would perhaps have been too warm to race in. Arm bands, such as cut off tube socks, have been worn by 'seasoned' wheelchair road racers (Plate IV.2).

The arm bands may be effective in their prevention of arm abrasions. However, perhaps those athletes who sustained arm abrasions did not use arm bands. Perhaps there is a need for more education regarding the benefits of protective equipment. Furthermore, perhaps an increase in the numbers of athletes who wear arm bands, would reduce the number of abrased arms in wheelchair sports.

Leg straps are a controversial inclusion with the other pieces of protective equipment. Since injury recording systems in wheelchair sports are only recently being developed, it is unlikely whether the risk of injury with or without leg strapping is known. Perhaps falling with the legs strapped into the wheelchair, is a greater source for further injury than falling free of the wheelchair. Further research is necessary to substantiate these hypotheses.

It is inferred that the few pieces of protective equipment used by wheelchair athletes did not entirely prevent sports injury. It is also known that few types of protective equipment worn in able-bodied sports prevent injury as they were designed. As Gallman astutely commented "if all protective equipment was as successful in preventing injury as mouthguards, there would be very few sports injuries" (Gallman in Easterbrook, 1987, p. 184).

A. Treatment of Reported Injuries

Nearly one fourth (25%) of all athletes reported no treatment for any injury they incurred through wheelchair sports participation, training, or competition. Perhaps this percentage was an indication of the level of seriousness of the injuries. Either the injuries incurred were less serious in nature, or the athlete's interpretation of the injuries was more lenient. Only one-third (30.8%) of all injured athletes sought any form of medical assistance, while barely 4% (3.8%) combined the medical advice offered and their own treatment. Conversely, an outstanding 40.9% of the athletes treated their injuries themselves. More than 50% of athletes who sustained teeth injuries (66.7%), abrasions (66%), blisters (62.5%), or pressure sores (57.15%) treated themselves. Athletes who sustained more serious injury types

Plate IV.2 Cambered Wheels and Arm Bands such as pressure sores, fractures, dislocations and concussions sought some form of medical assistance or self-treatment.

It is interesting that many athletes have learned to manage pressure sores themselv- According to Bedbrook (1985), complicated pressure sores are a major threat to the health and independence of spinal cord injured people (Bedbrook, 1985, p. 73). In fact, multiple pressure sores which involve bone and joints can be the cause of death in less than 6 weeks if they are left unattended (Burke and Murray, 1975, p. 58). However, perhaps so many pressure sores (57.1%) were self-treated because athletes detected the pressure sore development early.

Those athletes who suffered dental injuries (66.7%) or inflammation (40%) also sought treatment for their injuries. Since the degree of dental damage or inflammatory injury was not reported, conclusions regarding the seriousness of injury and the treatment rendered were not correlated.

Of all the wheelchair sports injuries that were reportedly treated, the 'les autres' classification of athletes were most likely to treat their own injuries (56.8%), followed by the spinal cord injured athletes (40.6%) (Figure IV.12). Remarkably, 42.9% of injured amputee athletes did not treat their own injuries or seek medical advice or treatment for their injuries. Perhaps amputee injuries were related to the use of their prothesis. Such irritatons to the stump could have been minor in nature.

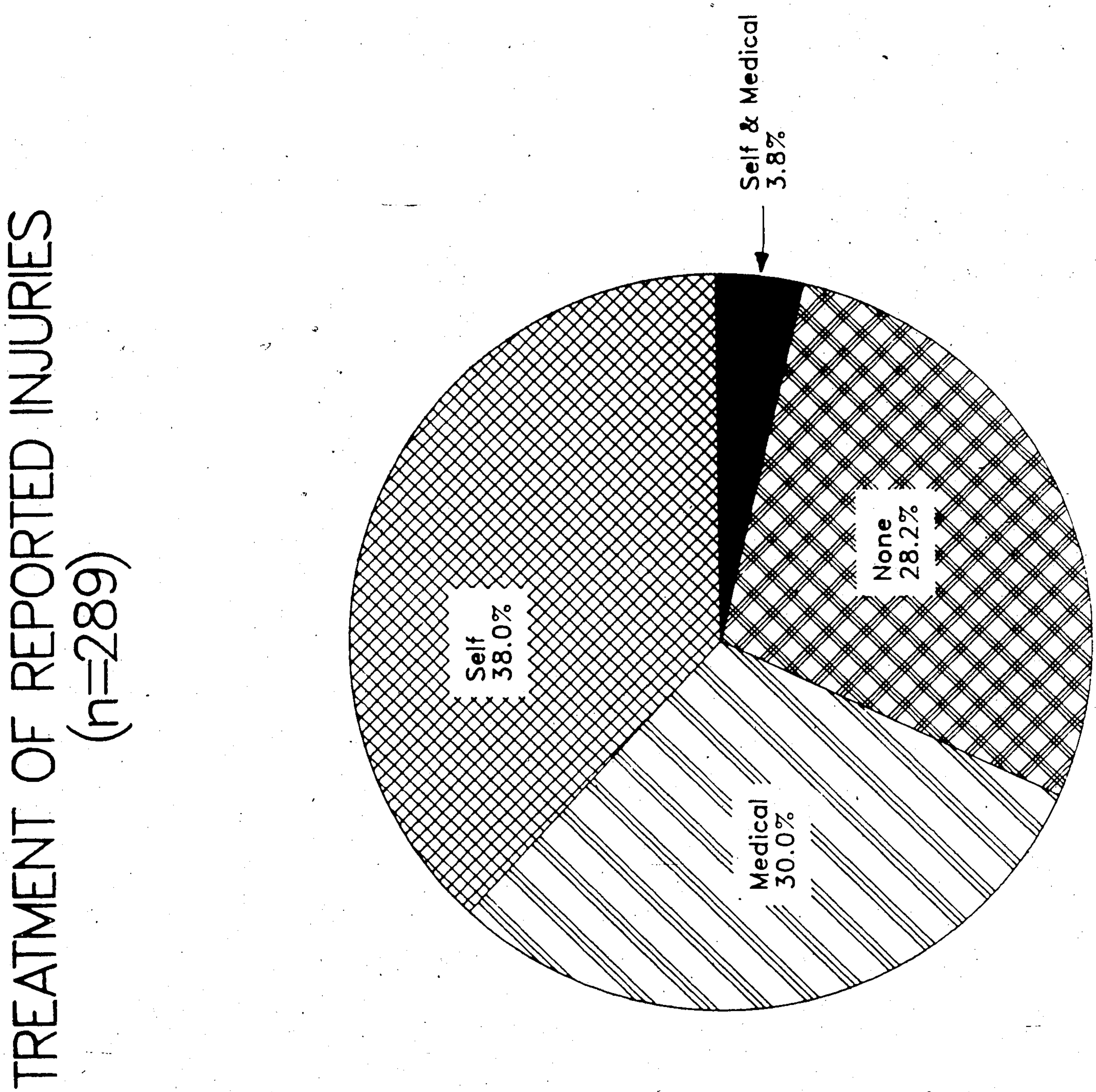


Figure IV.12 Treatment of Reported Injuries

Chapter V

Conclusions and Recommendations

Ah, but a man's reach should exceed his grasp

(Richard Browning).

Since their formal inception in 1948 as an adjunct to traditional rehabilitation, wheelchair sports have become more than a passing interest to many physically challenged people. Initially, sports were a welcome diversion from the boredom of hospital life. Discontented just to participate in athletics, many wheelchair athletes began to train, to dedicate more time toward wheelchair design, and to approach wheelchair sports competition physically and mentally prepared for victory. Throughout the twentieth century, wheelchair sports have increased in popularity and diversified in sports events. Both the competitor's age and their level of competition have risen. Wheelchair athletes have performed internationally at world class standing. The catalyst behind many of the progressions and technological advances in wheelchair sports has been man's inherent desire to be the best: to wheel faster, to throw farther, and to score more points.

Although wheelchair sports participation has proved to be physically beneficial and has provided a great atmosphere for comaradarie, character development, and learned skills, it is a source of injury. Sports injury is an unfortunate interruption in sports performance; its impact on athletes' level of sports participation is devastating. Broken bones, sprains, torn muscles, or inflammation in the upper limbs may prevent physically challenged athletes, not only from training and competition in sports events, but also may eliminate their ability to wheel, crutch-walk, or drive a car. However, few sports medical personnel have researched or documented the etiology of sports injuries to wheelchair athletes.

This study on sports injuries to Canadian wheelchair athletes was conducted to provide descriptive statistical information to athletes, coaches, and sports medical personnel.

The data demonstrated the basic relationships of sports injury occurrence to disability, age, residency, protective equipment, wheelchair design, and competition level. The data analysis alluded to several cause-effect relationships regarding specific patterns of sports injury that were identified. Overall, the injury statistics of this study underestimate the total frequency of sports injuries to all Canadian wheelchair athletes.

1. The most common injuries sustained were b[illegible]s (23.2%) and abrasions (21.5%). The most widespread injury throughout all sports events was muscle strains, while dislocations were among the most rare injury sustained.
2. The body parts most frequently injured were the hands (20%), shoulders (15.5%), fingers (11.8% and arms (10%). The sports in which the highest incidence of injury occurred were the popular sports of basketball, road racing, rugby, and track.
3. Eighty percent (80%) of the 90 athletes competed in an average of 5 competitions per year, in 35 different sports. The modal level of training was 6-10 hours per week.
4. Seventy-one percent (71%) of wheelchair athletes used protective equipment for training, participating or competing in wheelchair sports. Gloves (60%) were the most commonly worn piece of protective equipment throughout all sports. Of all athletes who used protective equipment, 84.4% wore gloves.
5. Fewer than one third (30.8%) of wheelchair athletes sought medical assistance or advice for their sports injuries, 40.9% treated themselves, and a handful (3.8%) combined the medical advice offered and their own treatment.
6. Thirty-two (32) varieties of wheelchair models were used by athletes in this study. As many as four (4) wheelchairs belonged to one athlete who competed in two sports.

A. Recommendations

In conclusion are 6 recommendations to wheelchair athletes who participate competitively or recreationally in wheelchair sports. These recommendations pertain to injury prevention, sports equipment, the environment, and fitness training.

1. It is recommended that wheelchair athletes acquire and wear protective equipment, such as helmets and gloves, which provide protection against the dangers associated with high speed travel. Protective equipment are an important means of injury prevention in all sports especially: road racing, downhill sledge skiing, and wheelchair rugby. Although wheelchair rugby players do not attain the same high speeds as road racers or sledge skiers, they are often 'out of control'. Due to their high lesion level, quadriplegic rugby players have poor balance and a slow hand-eye reaction time. These are a consequence of their genéral lack of upper limb and postural musculature. Thus to offset their chance of injury, it is recommended that appropriately sized and designed protective equipment be worn.

   Second, it is recommended that wheelchair athletes continue to invest time and energy into the discovery of the most efficient, well-constructed, sport specific, wheelchair designs. Wheelchair designs should: continue to ensure proper individual fit according to the variation in body dimensions, be relatively light, yet durable, and be well-suited to the demands of each sports event. Perhaps sports specific, individualized wheelchair designs will influence the type and number of injuries caused by the wheelchair. The design of the wheelchair must also comply with the rules of wheelchair design specified for each sports event.

   The third guideline is to limit the development of unnecessary overuse injuries by monitoring the training site and surface. The direction of travel both on the track and on the shoulders of deserted roads should vary. Athletes will want to avoid training on roads where the grade of the shoulders is steep, and preferably train longer distances with equal numbers of corners in each direction (ie. both directions on a track). Athletes who train on roads should choose those roads which are less busy. The chance of accidents with other vehicles decreases markedly when training takes place on deserted or less frequently travelled paved roads.

Fourth, it is recommended that wheelchair athletes seek medical advice from available sports medical personnel regarding sports injury, its first aid treatment, rehabilitation, and future prevention. Preventitive measures should be taken regarding proper warm-up and regular stretching routines. Athletes may often knowingly place themselves at risk of injury. Athletes who consciously ignore early signs of an injury, or omit appropriate warm-up or stretching exercises predispose themselves to sports injury. Once athletes detect signs of an overuse injury, or require emergency first aid for an acute injury, they should immediately contact sports medical personnel. For elite athletes, injury-free time is crucial. The sports medical support staff member is trained to assist in the treatment and rehabilitation of injured athletes while maintaining the atheltes' aerobic conditioning and skill level.

Finally, the athletes must obtain a coach, sports medical personnel, and access to fitness evaluation. The coach should have the knowledge and expertise to provide technical feedback on sport specific techniques, to arrange regular fitness testing, and to prescribe individually designed yearly training schedules for all wheelchair athletes. The coach should have an education, interest, and general understanding of sports injury, wheelchair sports and equipment. Access to sports medical personnel who are willing to administer appropriate first aid care and rehabilitation to wheelchair athletes with sports injuries should be found. Regular fitness testing which monitors wheelchair athletes' muscular strength, endurance, power, cardiovascular condition, and anthropmetric dimensions should become the joint responsibility of the coaches, the sports medical staff and the athletes.

In the new field of sports medicine for wheelchair athletes, many more research papers need to be written. Although the ground work has now been laid, few specific topics have been researched. Some of the suggested areas for further research include:

1. the relationship of wheelchair injury occurrence and the effectiveness of protective equipment worn in wheelchair sports,
2. winter and summer climate and its effects on wheelchair athletes,
3. the similarities of the etiology of able-bodied and disabled sports injuries,
4. the biomechanical analyses of wheelchair sports,
5. and the relationship of sport specific training and injury

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Appendix A: Hierarchy of Maslow

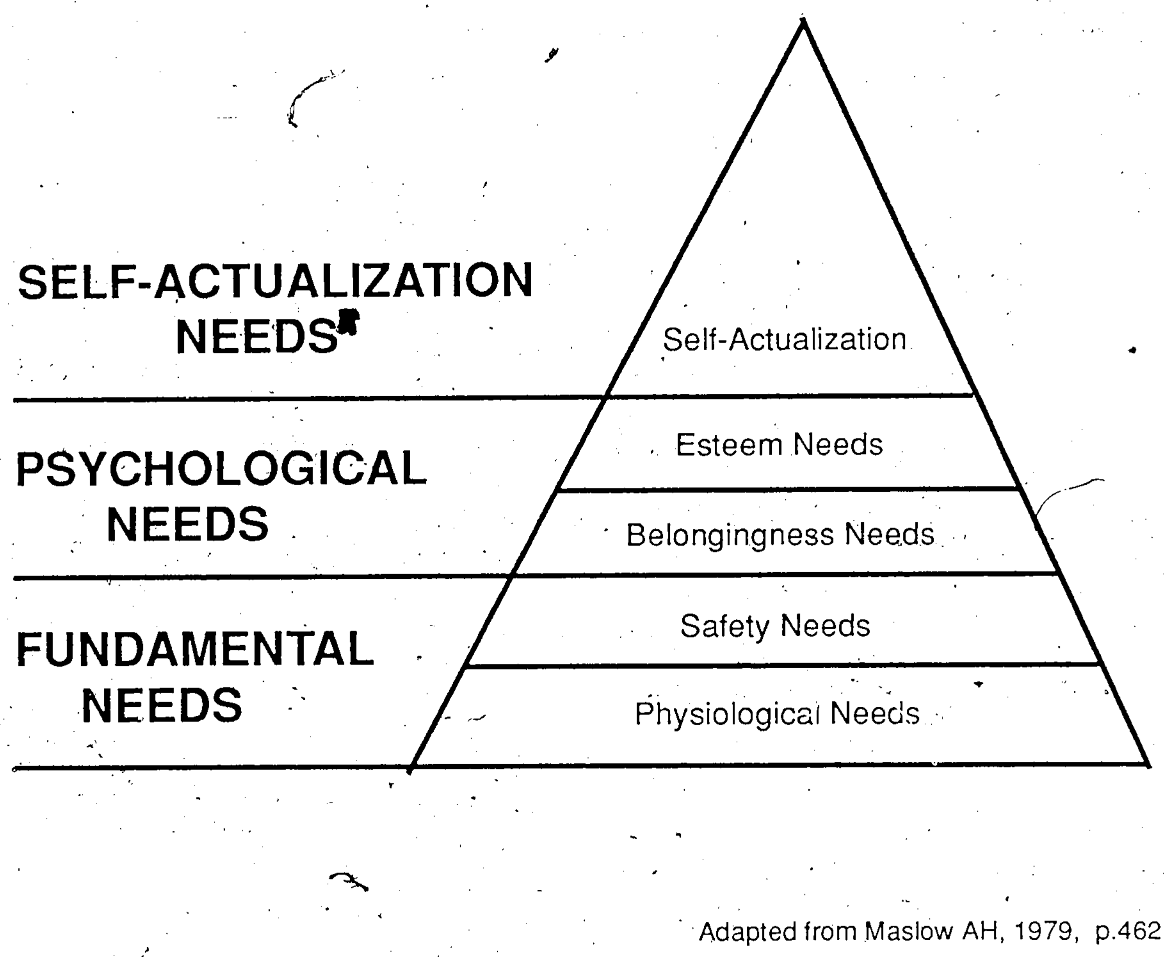


Figure A.1 Hierarchy of Maslow

Appendix B: Athletic Participation

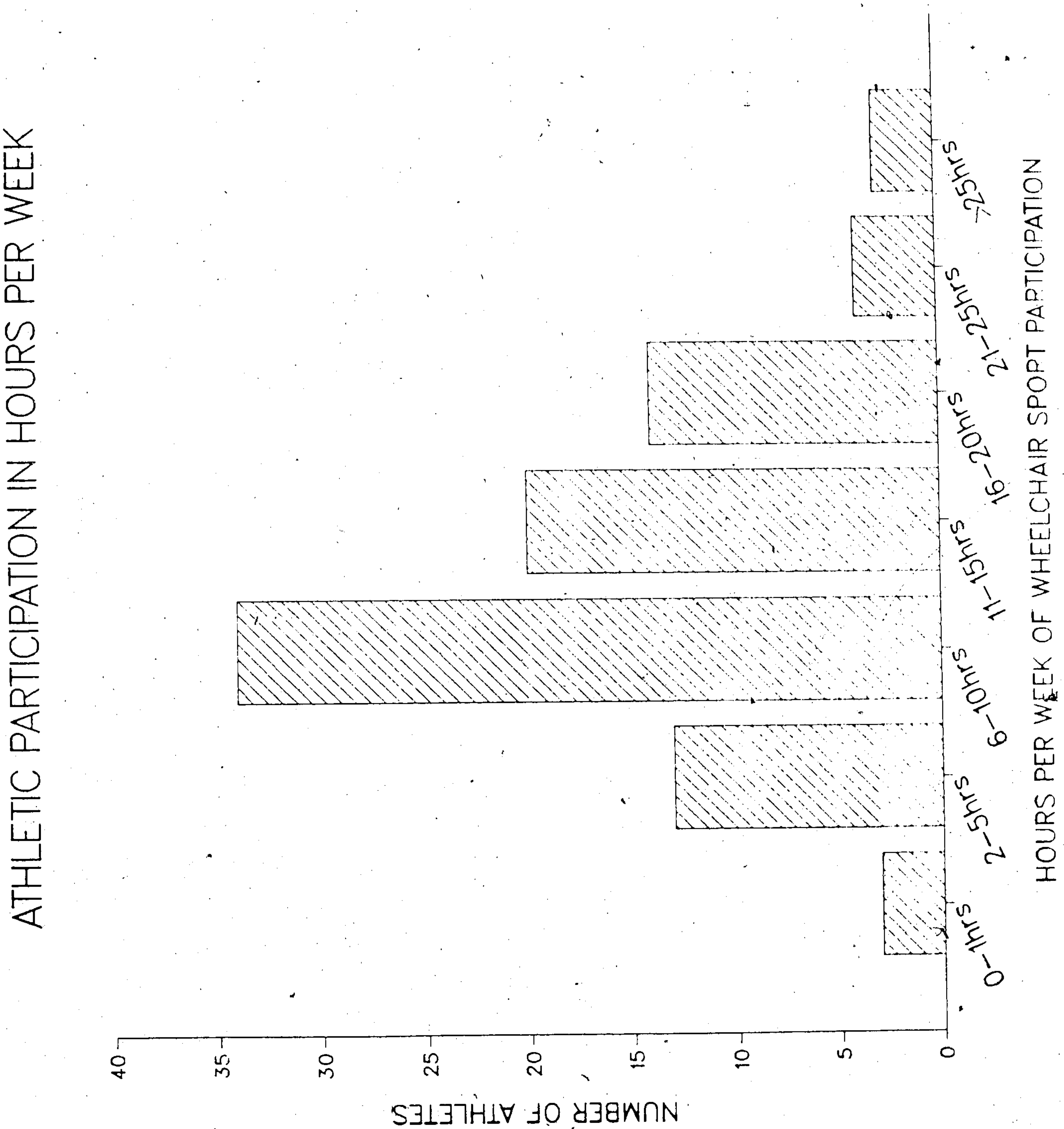


Figure B.1 Athletic Participation in Hours Per Week

Appendix C: Wheelchair Sportsmedicine Questionnaire

SPORTS INJURY: A NATIONWIDE SURVEY OF WHEELCHAIR ATHLETES REGARDING THE INJURIES THEY SUSTAIN THROUGH SPORT TRAINING, COMPETING, AND PARTICIPATING.

W ELCHAIR SPORTSMEDICINE QUESTIONNAIRE

Please return this completed questionnaire to:

Wheelchair Sportsmedicine Questionnaire

Dr. R.D. Steadward, Director
Research & Training Centre for the
Physically Disabled
Department of Physical Education & Sport Studies
University of Alberta
Edmonton, Alberta
T6G 2H9

WHEELCHAIR SPORTSMEDICINE QUESTIONNAIRE

A. Sport Participation

1. What is the highest level of competition you have participated? (Please circle the appropriate response)

   1. Provincial   2. National   3. International

2. How many years have you competed at the Provincial level or higher?

   ______ yrs
   (Please indicate your answer in the closest half year)

3. How many competitions have you participated in to date?

   __________.
   (Please indicate your answer to the nearest ten)

4. What is the <u>average</u> number of hours per <u>week</u> you are presently involved in <u>all</u> wheelchair training, competing, and participating? (Please circle the appropriate response)

   1. 0-1 hr   4. 11-15 hrs   7. 21-25 hrs
   2. 2-5 hrs   5. 16-20 hrs   8. over 25 hrs
   3. 6-10 hrs

5. How many <u>days</u> per week are you involved in all wheelchair sport activities? ______ days

6. Please indicate the sport and the type (design) of chair used:

	SPORT	TYPE (custom fit OR 2nd hand)
1. Individualized Design	1. ____________	1. ____________
	2. ____________	2. ____________
	SPORT	MANUFACTURERS (eg. Quadra,Quickie, etc.
2. Commercial	1. ____________	1. ____________
	2. ____________	2. ____________

7. Do you generally wear protective gear? (Please circle the appropriate response)

   1. yes   2. no

   If yes, do you use...? (Please circle <u>all</u> appropriate responses)

   1. gloves   4. straps
   2. armband(s)   5. other ____________ (Please specify)
   3. helmet

7. Using the chart below, please indicate any injury(s) that you recall sustaining during training, participating and/or competition in wheelchair sports.

INJURY	BODY PART INJURED (indicate left or and body part)		FREQUENCY OF INJURY				SPORT BEING PLAYED AT TIME OF INJURY	TREATMENT		
	BODY PART	L or R	once	weekly	monthly	occasionally		NONE	SELF-TREATED	MEDICAL/THERAP
1. Abrasion (scrapes)										
2. Blisters										
3. Lacerations (cuts requiring stitches)										
4. Contusions 1. muscle bruise										
2. bone bruise										
5. Strain (muscle pull)										
6. Inflammation (swelling) 1. tendinitis										
2. bursitis										
3. other (please specify)										
7. Other 1. concussion										
2. dental injury										
3. eye injury										
4. dislocation										
5. fracture										
6. pressure sore										
7. other... (please specify)										

8. Please indicate the number of years to the closest half year you have participated in any of the following sports since you became disabled.

SPORT	NUMBER OF YEARS PARTICIPATING	NUMBER OF YEARS COMPETED IN SPORT Prov.	Nat'l	Int'l	SPORT	NUMBER OF YEARS PARTICIPATING	NUMBER OF YEARS COMPETED IN SPORT Prov.	Nat'l	Int'l
Archery					Skiing (sledge)				
Basketball					Softball				
Boccia/Bowling					Swimming				
Field 1. discus					Table Tennis				
2. javelin					Track Events 1. sprints (up to 400m)				
3. club throw									
4. shotput					2. mid-distance (800m - 5000m)				
CP Soccer									
Horseback Riding					Tennis				
Kayaking/Canoeing					Volleyball				
Road Racing/Marathons					Weight-lifting				
Riflery					Other				
Rugby/Murderball					Other				
Sailing					Other				
Skiing (outrigger)									

B. General Information

9. Date ________

10. Residence: City ________ Province ________

11. Gender: Male ____ Female ____

12. Birthdate ___/___/___
day mo yr

13. Disability ________

14. Classification (Please circle appropriate response)

1. amputee: A1__ A2__ A3__ A4__ A5__ A6__ A7__ A8__ A9__
2. CP/les autres: 1__ 2__ 3__ 4__ 5__ 6__ 7__ 8__
3. wheelchair: IA__ IB__ IC__ II__ III__ IV__ V__ VI__

15. If acquired disability, please indicate specific cause. (Please circle appropriate response)

1. motor vehicle (car)
2. motorcycle
3. industrial accident
4. recreation, sport-related accident
5. other ________
(Please specify)

16. If acquired what was the year you became disabled? (Please specify month and year) ______/______
month year

Appendix D: Questionnaire Used by Curtis in 1981

Wheelchair Sports Medicine Questionnaire

The investigation of types of injuries suffered in different sports has spawned the field of sports medicine. By understanding what kind of injuries can be expected in a particular sport, coaches and athletes are better able to eliminate them with proper training and equipment.

A very limited amount of this type of information is available in wheelchair sports. To begin to gather more data, would you please take the time to complete this questionnaire and either enclose in an envelope, or fold form so address is on the outside, and staple or tape shut and mail to: Kathy Curtis, RPT, 4056 Bismark Drive, San Jose, California 95130.

Date ____________

1. Residence City ____________ State ____________
2. Male ______ Female ______ (please check)
3. Age ______
4. Disability ____________ Level of injury ____________
5. Year of onset ____________ Cause ____________
6. NWAA classification ____________ (most recent)
7. NWBA classification ____________
8. Indicate the number of years you have participated in any of the following sports since the onset of your disability.

______ Archery	______ Martial arts	______ Table tennis
______ ATVs / Motorcycles	______ Pilot (airplane)	______ Track events up to 1 mile
______ Basketball	______ Pool / Billiards	______ Tricycle, handcrank
______ Bowling	______ Raquetball	______ Tennis
______ Downhill racing	______ Riflery	______ Volleyball
______ Field events	______ Sailing / Boating	______ Water-skiing
______ Football	______ Skiing (3 track) feet	______ Weightlifting
______ Golf	______ Skiing (sled device)	______ Yoga
______ Horseback riding	______ Slalom racing	______ Other: ______
______ Kayaking	______ Softball	______ Other: ______
______ Marathons / Road racing	______ Swimming	______ Other: ______

9. Average number of hours *per week* you are *presently* involved in *all* of the above sports:

   ___ 0-1 hour ___ 2-5 hours ___ 6-10 hours ___ 11-15 hours ___ 16-20 hours ___ 21-25 hours ___ Over 25 hours

10. Number of days *per week* you are involved in all of the above sports activities: ____________
11. Briefly describe your routine immediately (1 hour) prior to your involvement in an athletic event or heavy workout.

    ____

12. Do you wear protective gear? (gloves, helmet, safetyglasses) ____________

    Explain ____________

13. Briefly describe your routine immediately following a workout or athletic event. ____________

Please list appropriate date of injury, injury code, body area code, and sport code for each injury you can remember. For a recurrent or active problem, please indicate. Describe treatment received, if any.

INJURY CODES

1-Arthritis/joint disorder
2-Blisters
3-Blood pressure disorder
4-Bronchitis/asthma
5-Bursitis
6-Decubitus/pressure area
7-Dental injury
8-Dysreflexia
9-Eye injury
10-Fracture
11-Hand weakness, numbness (carpal tunnel syndrome)
12-Heart problems
13-Head injury concussion
14-Laceration or abrasion of skin
15-Muscle pull
16-Skin infection
17-Spinal injury
18-Sprain or strain
19-Temperature regulation disorder (hot or cold)
20-Tendinitis
21-Other ______
22-Other ______
23-Other ______

BODY AREA CODES

A -Head
B -Eye
C -Ear
D -Face
E -Teeth
F -Neck
G -Shoulder
H -Upper arm
I -Elbow
J -Forearm
K -Wrist
L -Hand
M -Fingers/~~Thumb~~
N -Chest, above waist
O -Abdomen, below waist
P -Pelvis
Q -Hip
R -Thigh
S -Knee
T -Lower leg (calf)
U -Ankle
V -Foot
W-Toes
X -Spine - cervical
Y -Spine - thoracic
Z -Spine - lumbar
AA-Other ______
BB-Other ______
CC-Other ______

SPORT CODES

AR-Archery
ATV-All terrain vehicles & Motorcycles
BAS-Basketball
BOW-Bowling
DOWN-Downhill racing
FLD-Field events
FOOT-Football
GO-Golf
KAY-Kayaking
RR-Marathoning, road racing
MAR-Martial arts
AIR-Pilot (airplane)
POO-Pool/Billiards
RAC-Racquetball
RIF-Riflery
SAI-SAiling/Boating
SKI-Skiing (3 track)
SLE-Skiing (sled type)
SLA-Slalom racing
SOF-Softball
SWI-Swimming
TT-Table tennis
TR Track events (up to one mile)
TRI Tricycle (handcrank)
TEN Tennis
VOL-Volleyball
WAT-Water skiing
WL-Weightlifting
YO-Yoga
OT-Other ______
QT-Other ______

DATE(S)	INJURY CODE	BODY AREA CODE(S)	SPORT CODE	IS PROBLEM ACTIVE, RECURRENT, RESOLVED?	TREATMENT (Include medical test X-rays or medication, self-treatment)

For additional injuries, use plain sheet of paper and enclose with questionnaire

FOLD HERE

Return Address

______

______

Affix postage

Kathy Curtis, RPT
4056 Bismark Drive
San Jose, CA 95130

Appendix D: Winter Sports Illustrated

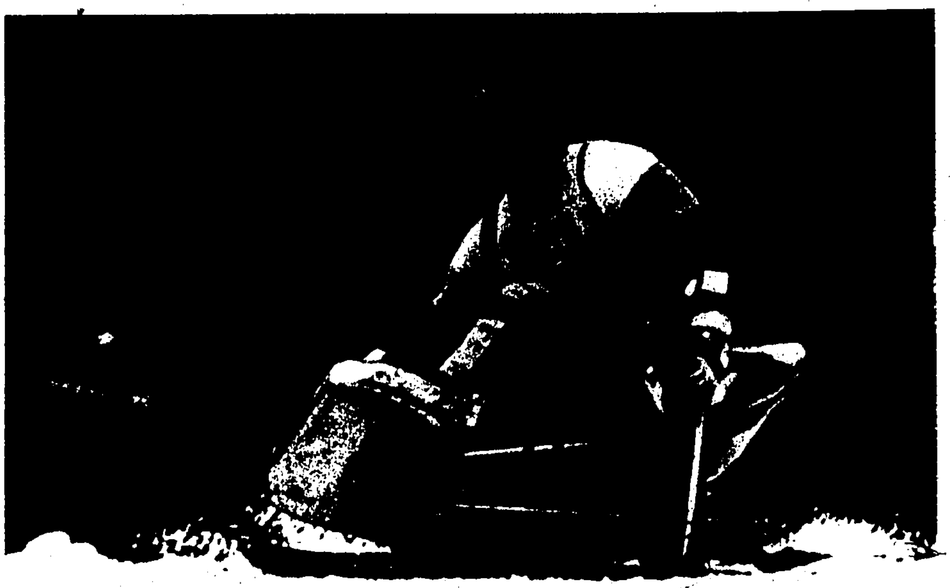


Plate IV.1 Sledge Hockey

Plate IV.2 Outrigger Skiing

Plate IV.3 Sit-Skiing

Appendix F: Classification

The aim of the classification system is to ensure fair play and to eliminate, as far as possible, injustices between participants in the same class. There are many classifications for disabled sports participants including developmentally disabled, blind, cerebral palsy, amputee, and spinal cord injured. In wheelchair sports participation, the latter three disabilities together with a class of other neuromusular and congenital disorders, compete in wheelchair sports.

A classification system may be devised on a medical basis or on a functional basis. At the beginning of the annual Stoke-Mandeville Paraplegic Games in the 1950's, a classification system on a medical basis was introduced. Since this time, similar systems have been introduced for amputee athletes, cerebral palsied athletes, and les autres (Eijsden-Besseling, 1985, p.288). Each of these disabilities have their own sports organizations, provincial associations, and national and world competitions. However, there are also international competitions such as the World Games, the Olympics for the Disabled, and specific sports World competitions which integrate competitors from a number of disability classes. Thus, although SCI, amputees, CP, and les autres all have their own classification system, they all are included within wheelchair sports classification.

Cerebral Palsy Classification System

Cerebral palsy (CP) is a non-progressive, often congenital, brain lesion which causes variable impairment of muscle action commonly involving posture, coordination, speech, vision, hearing, and perception (CPISRA, p. 26). The variability of CP symptoms complicate the classification of these athletes. Thus, the CP classification system measures the CP athletes' functional level in relation to their sports event.

Medically, CP individuals are classified topographically according to the number of affected limbs (for example, monoplegic, hemiplegic, or triplegic) and tone. CP's may have increased, decreased, or fluctuating muscle tone. It is the great variety in types of tone which make classification of some CP athletes challenging. Examples of tone include ataxic, athetoid, dystonic, or tremor.

There are eight divisions in the CP sport classification system. CP1 athletes are the most disabled, and the CP8 class are the least disabled athletes. In wheelchair sports, only CP1 to CP4 are eligible for competition. The remaining classes comprise ambulant athletes who are less disabled. The equivalent CP class competitors and the wheelchair classes are:

CP1,CP2..........eligible for CP soccer; CP track races

CP3..............class III or IV wheelchair sports

CP4 ....class IV or V wheelchair sports

Those CP athletes classed as CP5, CP6, CP7, or CP8 may compete in swimming events only at wheelchair games or competitions.

Recently, the les autres disability classes, who were classified using the CP classification system, established their own classification system. Classes L1, L2, or L3 are eligible for wheelchair sports competition in respective wheelchair sports classes of class III, class IV or V, and class V. F.2

C.P.I.S.R.A. (Cerebral Palsy International Sports and Recreational Association)
Classification System for Competitive Sports

Classes		
CP 1	*Quadriplegic*	-normally using electrical wheelchair
CP 2	*Quadriplegic*	-normally propel wheelchair with legs
CP 3	*Weak Quadriplegic or Triplegic*	-normally able to propel wheelchair with one or two arms slowly
CP 4	*Diplegic*	-use wheelchair for normal daily activities and sports events
CP 5	*Diplegic or moderate to severe Hemiplegic*	-may or may not use walking aids (i.e. cane(s) or crutch(es)
CP 6	*Quadriplegic Athetoid*	
CP 7	*Moderate to minimal Hemiplegic or moderate to minimal Quadriplegic*	
CP 8	*Minimal Handicap Group*	

Cerebral Classification: C.P.I.S.R.A. Classification and Sport Rules Manual, C.P.I.S.R.A., Secretariat, Balyeweg 26, 6874 AJ Wolfheze, The Netherlands.

Figure F.1 Classification A) Cerebral Palsy

I.S.O.D. (International Sport Organization for the Disabled
Les Autres Classification System - for Field Events

Classes

L1.... Wheelchair-bound; reduced function of muscle strength, mobility, and/or spasticity in throwing arm; poor sitting balance.

L2.... Wheelchair-bound with normal function in throwing arm and poor to moderate sitting balance; or reduced function in throwing arm, but good sitting balance.

L3.... Wheelchair-bound with *normal* arm function and good sitting balance.

L4.... Ambulant with or without crutches and braces; or problems with balance together with reduced function in throwing arm.
note: Athletes are allowed to use orthosis or crutches; L4 or L5 athletes can throw from a stand-still or moving position.

L5.... Ambulant with normal arm function in the throwing arm; balance problem; or reduced function in lower extremities.

L6.... Ambulant with normal upper extremity function in throwing arm and minimal trunk or lower extremity disability. Athletes in this class must be able to demonstrate a locomotor disability which clearly gives them a disadvantage in throwing events compared with able-bodied athletes.

Les Autres Classification I.S.O.D. Handbook, I.S.O.D. Office of the Secretary General, SHIF, Idrottens Hus, S-123 87 Farst, Sweden.

Figure F.1 Classification B) Les Autres

mputee Classification

An amputee is a term which refers to a traumatically acquired or congenital amputation of a limb or appendage. The amputee is classified according to the site and level of limb or appendage absence.

Similar to the cerebral palsied , the amputees have their own national body, provincial associations and sport organizations. Amputees are exempt from some international competitions such as the Stoke-Mandeville Games, but are included in the World Wheelchair Sports competitions and several international sports events competitions.

There are eight classes of amputees, who are classed according to their combination of missing appendages. The visually apparent class distinctions make the amputee classification procedure less compilcated. Functional assessment of amputees' sports events is seldom necessary.

The equivalent amputee calss for wheelchair sports competition are:

class A1.............class II wheelchair basketball (2 pts)

class A2, A3, A4.........class III wheelchair basketball (3 pts)

I.S.O.D. (International Sport Organization for the Disabled)

Classification Code - Amputees

Class A1.................. Double AK
Class A2.................. Single AK
Class A3.................. Double BK
Class A4.................. Single BK
Class A5.................. Double AE
Class A6.................. Single AE
Class A7.................. Double BE
Class A8.................. Single BE
Class A9.................. Combined lower plus upper limb amputations

A = Above   K = Knee
B = Below   E = Elbow

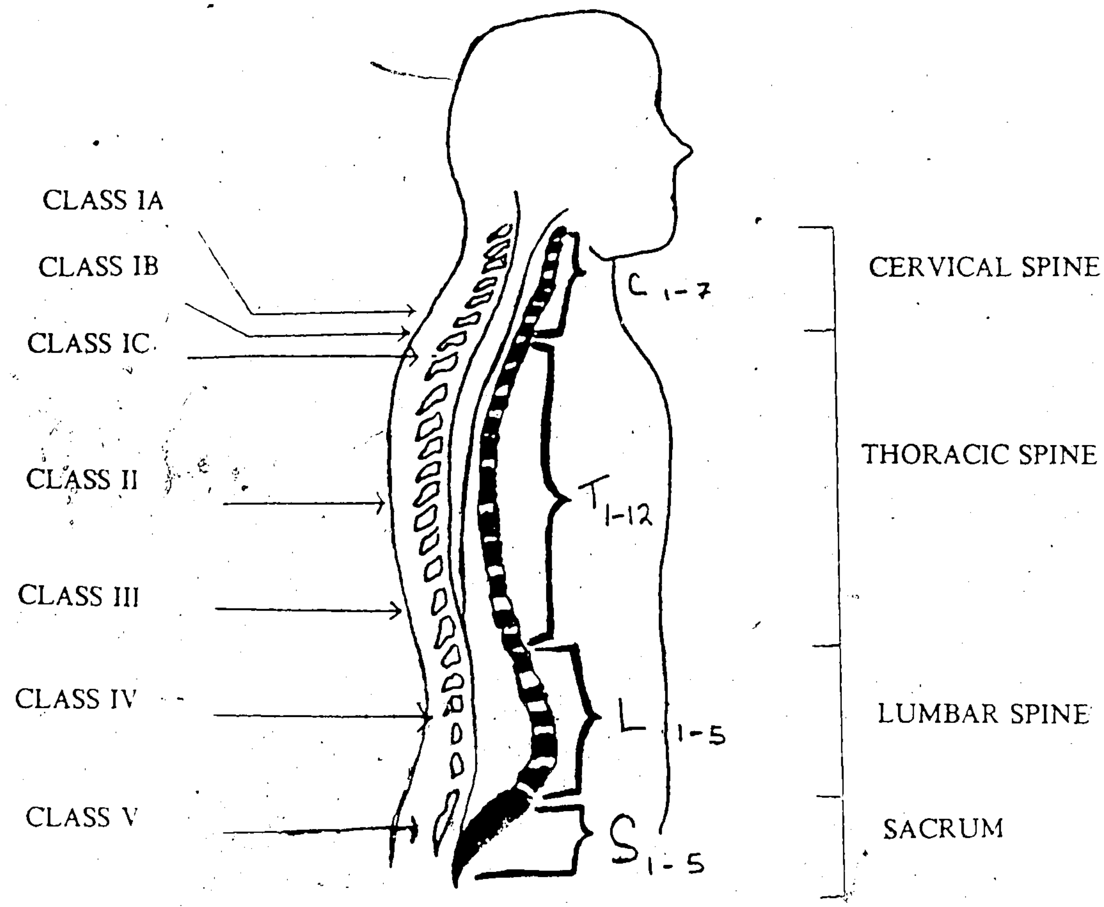
Amputee Classification I.S.O.D. Handbook, I.S.O.D. Office of the Secretary General, SHIF, Idrottens Hus, S-123 87 Farsta, Sweden.

Figure E.3 Classification C) Amputee

Spinal Cord Injured Classification

Spinal cord injury has been considered "one of the greatest tragedies of mankind" (Goodman, 1986, p. 96). The spinal cord, located within the vetebral column, is one of the most important organs in animals and man. This large nerve is the nervous center for sensory control and an essential link in the pathway for volitional motor control. If the spinal cord is crushed or severed by a knife, bullet, thrombosis or spinal fracture at any level, the result is partial or complete paralysis below the injury site. The degree of temporary or permanent loss of function is dependent upon the type of fracture, or damage to the spinal cord and the level of spinal cord lesion. The physical potential the athlete has in terms of muscle strength, flexibility, power, and balance are determined by these two factors.

The six class classification system of the spinal cord injured is based upon the medical classification of spinal cord injury together with the athletes functional ability in their sports event. The quadriplegic has the highest level of spinal cord injury and is classified in classes, IA, IB, IC, and II. Their respective levels of spinal cord injury are: cervical spine levels C6, C7, C8, and thoracic levels T1 to T5 (Figure VI:4).** All quadriplegics suffer from some degree of paralysis to all four limbs. The paraplegics comprise the remaining four classes, with injuries to the spinal cord at the levels of thoracic levels T6 to T10 (class III), thoracic and lumbar levels T11 to L3 (class IV), and lumbar and sacral levels L4 to S2 (class V). Class VI spinal cord injured athletes compete in swimming events only.



(Adapted from McCormack, 1983, p.46)

Figure F.4 Classification D) Spinal Cord

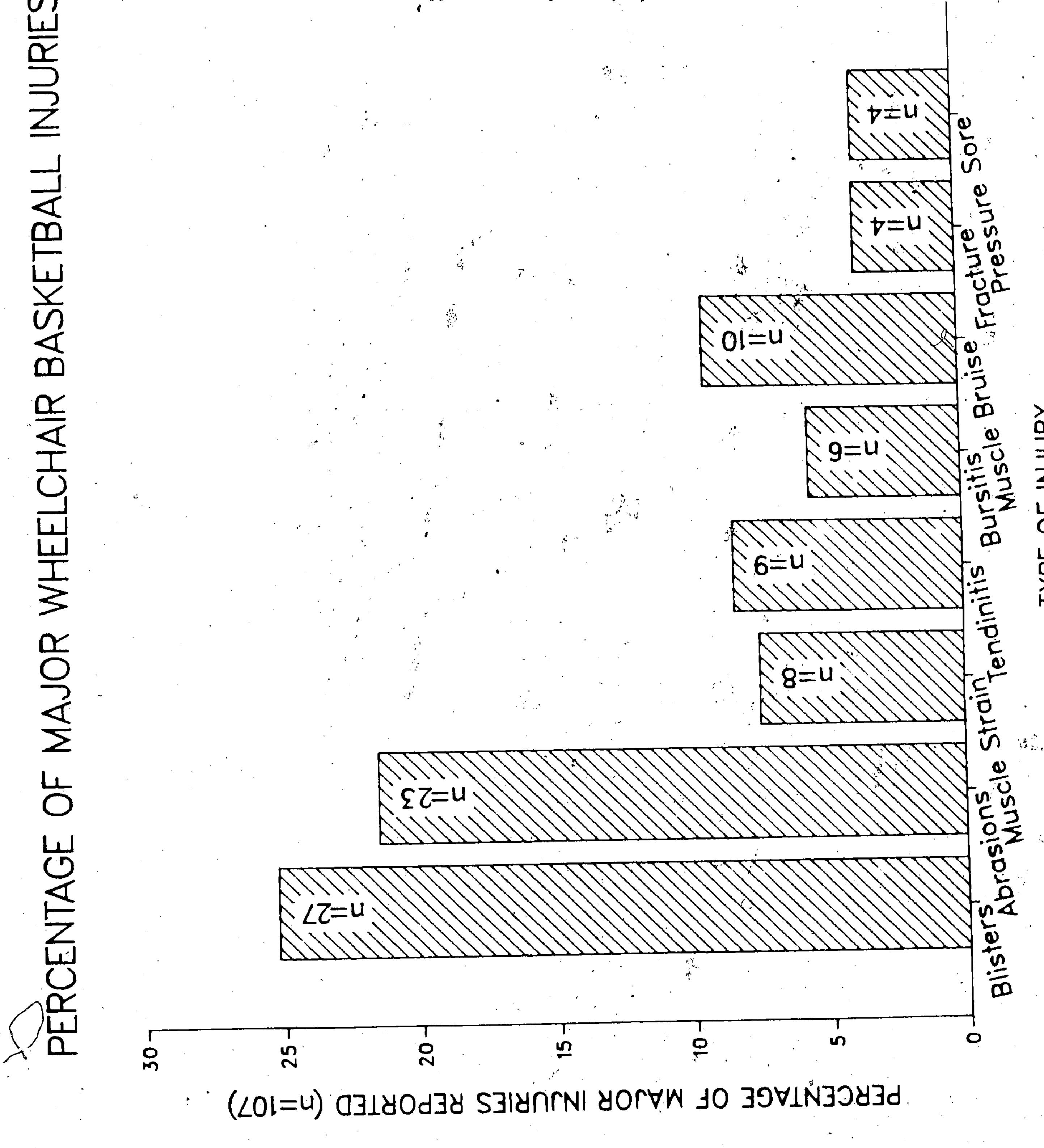


Figure G.1 Wheelchair Basketball

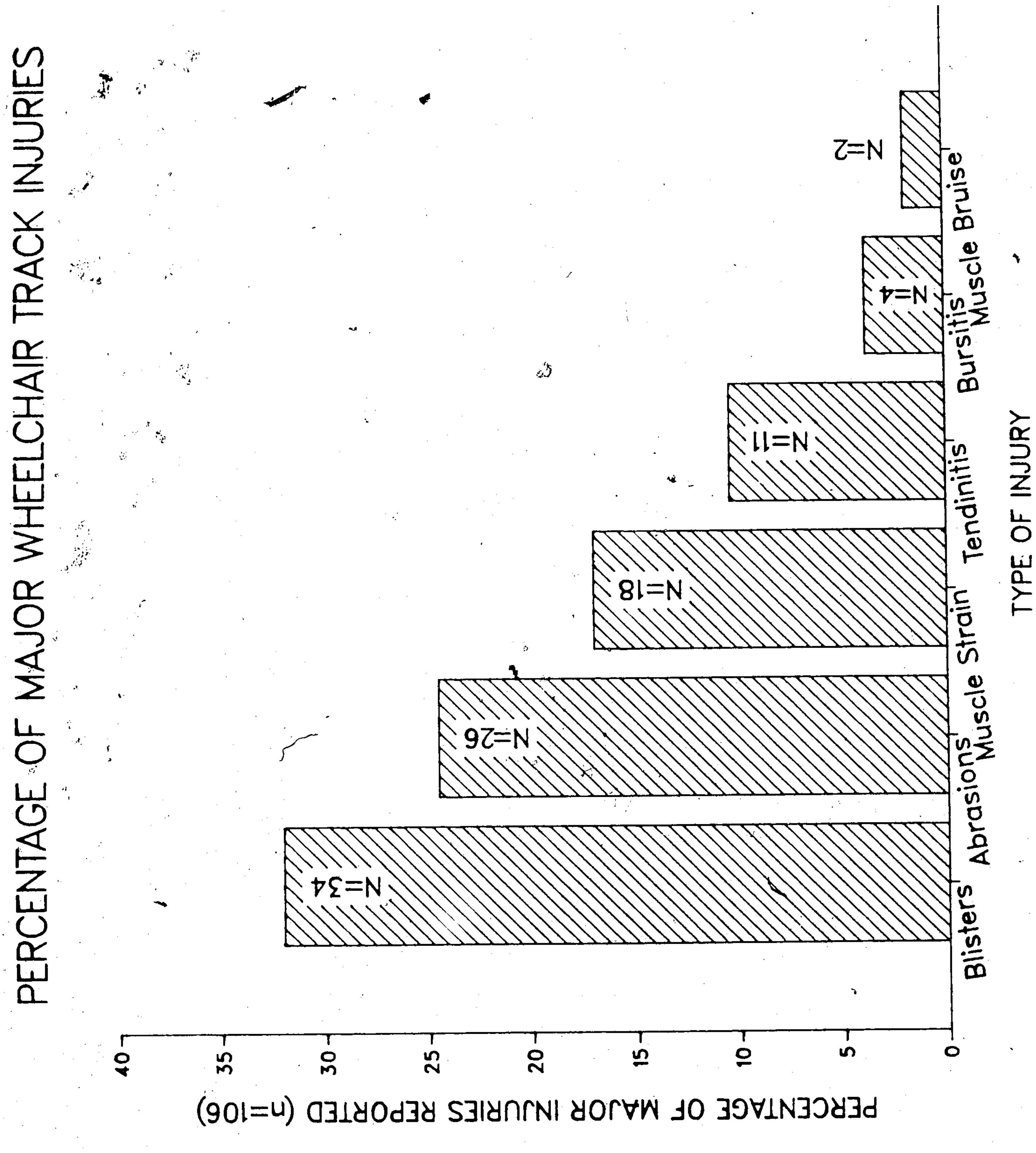


Figure G.2 Wheelchair Track Events

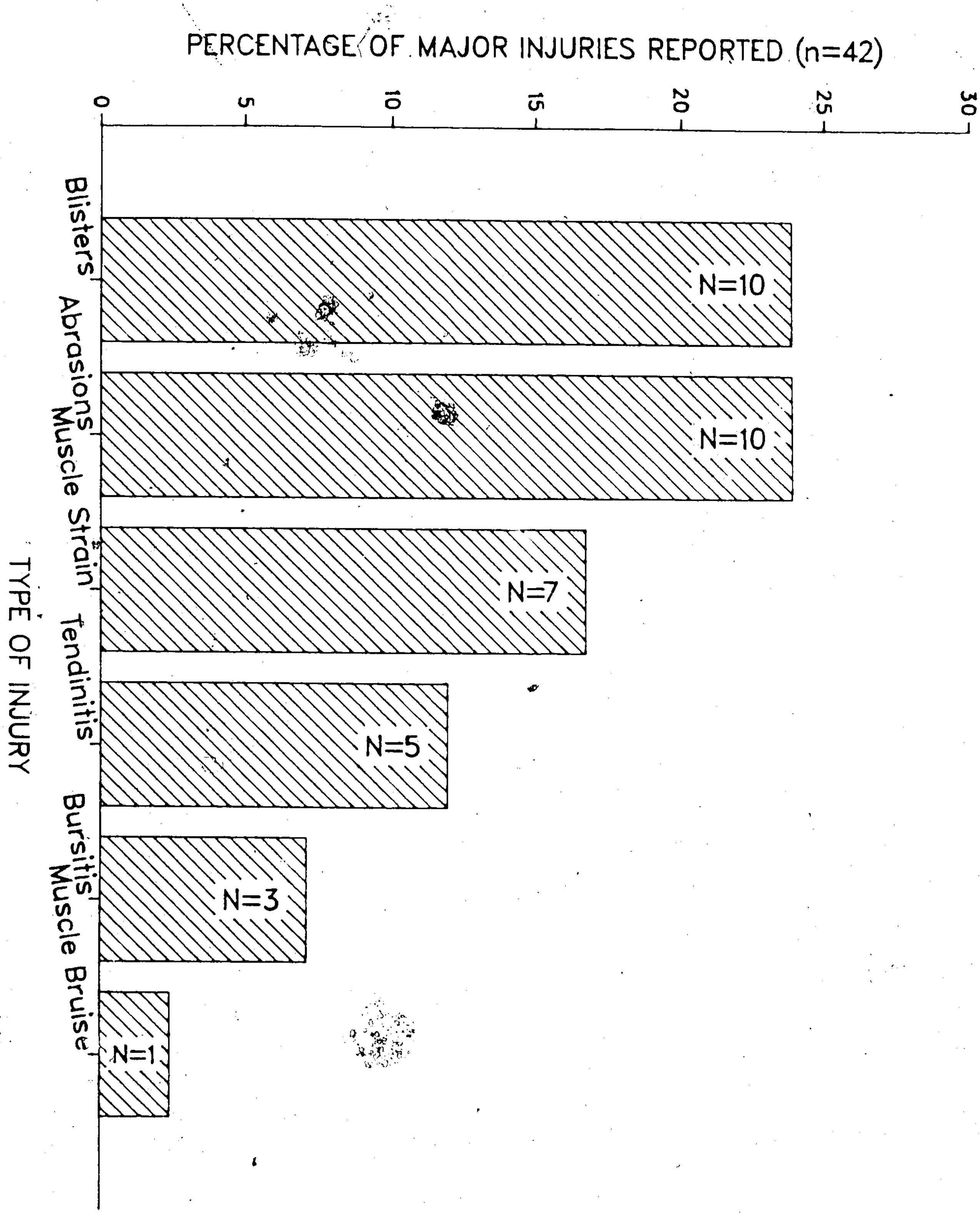


Figure G.3 Wheelchair Road Race

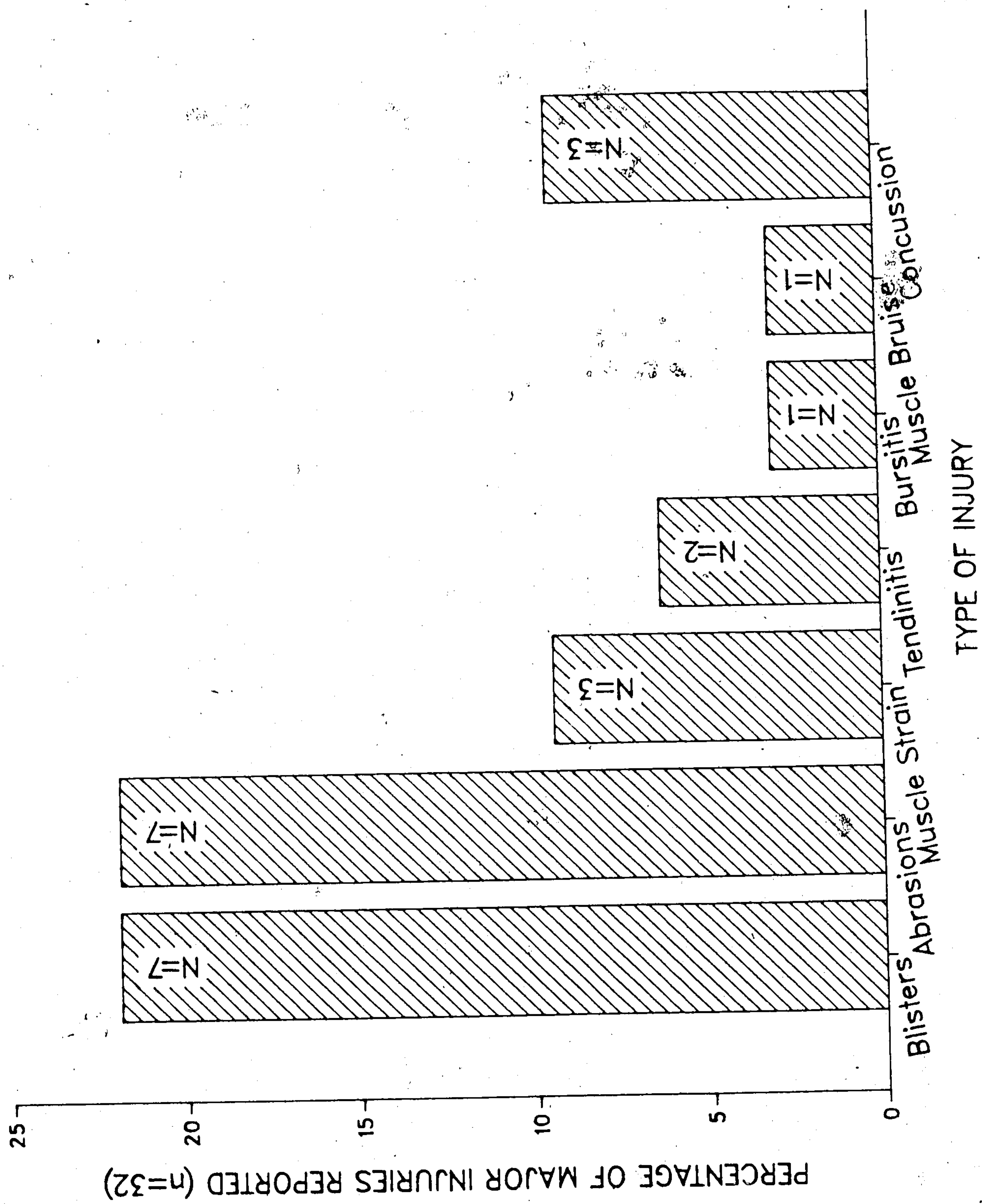


Figure G.4 Wheelchair Rugby

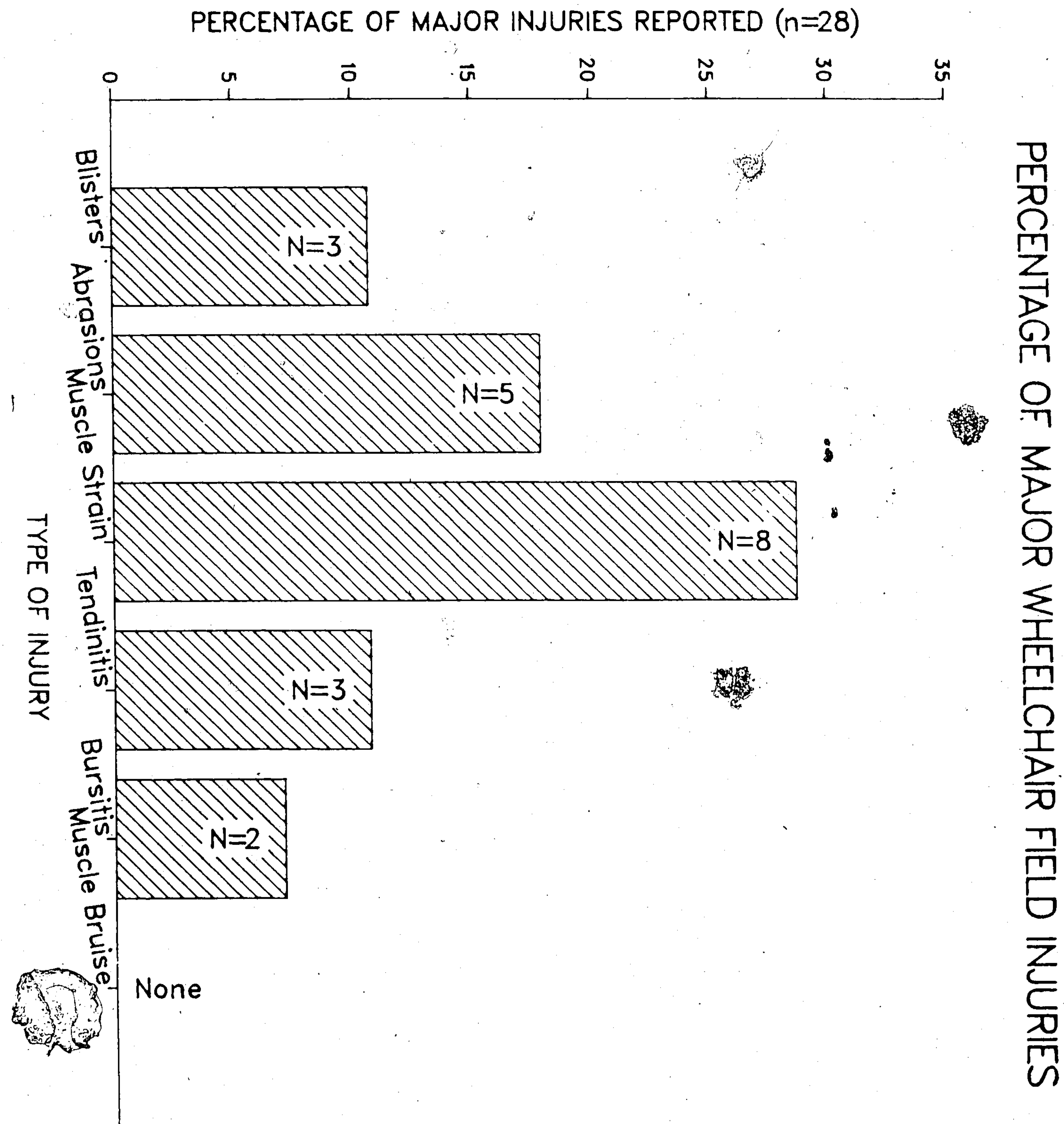


Figure G.5 Wheelchair Field Events

Appendix II: Quadriplegics and Temperature Regulation

Below their level of spinal cord lesion, paraplegics and quadriplegics do not have usual thermo-regulatory mechanisms. High level cervical lesioned quadriplegics are unable to conserve heat by vasoconstriction or to lower body heat by vasodilation. Their level of lesion interrupts the functioning of the autonomic nervous system. Unable to shiver or to perspire, they have no useful protective responses to hypothermic or hyperthermic conditions. Quadriplegics, similar to reptiles, assume the temperature of their environment (Burke & Murray, wheelchair athletes.

Appendix I: Reflections and Implications

A. Reflections

In retrospect, future research studies should be conducted in the field of wheelchair sports injury because:

1) information in this field is scarce,
2) many myths regarding the wheelchair athletes' successful performances, training methods, and wheelchair designs exist,
3) and many of the astounding accomplishments of disabled athletes have confuted the established medical limitations of these disabled athletes' capabilities.

First, the field of wheelchair sports injury is a broad and relatively unresearched field. The initial papers published by researchers pioneering in any new field of interest are little more than general descriptions of several variables. As in this descriptive study, these papers provide information which increases the fundamental knowledge of the new subject matter, and establishes the new field in the eyes of the general public and interested others. Once a knowledge base exists in a new field, theories can be postulated, and conclusions validated for their accuracy and generality.

Second, scientifically sound conclusions of specific controlled research studies would replace much of the trial and error judgements which customarily surround the relatively new field of wheelchair sports. Once the etiology of these sports injuries has been reported, the athletes, their coaches, the sports medical profession and interested others are encouraged to determine how these injuries happened, why they occurred, and what needs to be done to prevent their recurrence.

Further research studies which focus on the athlete, their sports-related injury occurrence, wheelchair design, training methods, and recreational and sporting pursuits, do not take away from the research dedicated to discovering a cure for spinal cord injury. All knowledge gained through research in wheelchair sports is beneficial to those disabled people who are active in sports and recreation, those disabled people who are inactive, and the general population. The general public's interest in wheelchair sports does not take away from their understanding of, and dedication to spinal cord research. Research to find a cure, to prevent the massive disabling effects damaged spinal cords have on the human body, is of considerable importance. However, like many of this world's disabling diseases, the afflicted individuals must learn to face their injury, and to cope with their life while a cure is being discovered. Feasibly, "a cure for spinal cord injury may not be found within the next decade. Many of today's disabled athletes will probably not witness the discovery or benefit from its application " (Hansen, 1988, p.G14).

Third to cope with an injury as devastating to the human body as spinal cord injury, and to continue to succeed in life is a feat of great magnitude. The medical profession in the early 1940's had little faith in the survival of severe spinal cord injured people. Yet, surrounded by the positive rehabilitative environment and atmosphere created through the wisdom of Sir Ludwig Guttmann and his followers, many disabled people not only lived but demonstrated that a physical disability need not prevent a person from reaching the pinnacle of excellence in sports (Crase, 1988, p. 4). Acceptance of the many challenges disabled people face, requires not only a great deal of courage, but an enormous amount of self-confidence. Sports have provided many disabled people with an avenue through which a positive self-image can be fortified.

People who have confidence in their personal worth, seem to be magnets for success and happiness. Their continued successful performances based on innovative wheelchair designs, modified sports equipment, skill, and dedication to individualized training programs are tremendous. Each new world record blurs the physiologically based limitations set for disabled athletes. To retain the respect of the medical profession in the minds and views of disabled athletes, scientifically conducted medical research must continue. Medical research ...t begin to keep pace with the technological advances and the physical accomplishments of the ...bled population and the impact these developments have on society's values and belie...

B. Implications

The following implications to future researchers in the field of wheelchair sports, sports medical personnel, wheelchair athletes, their coaches, the media, and the general public are based upon the results of this study. Just as each of these groups has specific interests in wheelchair sports, recommendations for their future contributions to this developing field are individual in nature.

(i) Future Researchers

In the new field of sports medicine for wheelchair athletes, many more research papers need to be written. Although the ground work has now been laid, few specific topics have been researched. Some of the suggested areas for further research include:

6. effective training programs and their effect on wheelchair sports performance,
7. the similarities of the etiology of able-bodied and disabled sports injuries,
8. the biomechanical analyses of wheelchair sports events,
9. the ideal pathways and specific techniques of wheelchair athletics,
10. the relationship of sport specific training and injury occurrence,
11. the relationship of wheelchair injury occurrence and the effectivenessof protective equipment worn in wheelchair sports,
12. winter and summer climate and its affect on wheelchair athletes,
13. effects of nutrition (pre-event, post event meals) and wheelchair athletes,
14. and the role of the wheelchair sports' coach.

Future researchers in the field of wheelchair sports, have several options for their choice of research design, means of data collection, and statistical analysis. Each research design has its own limitations. There are additional specific limitations in all research studies whose sample population is comprised of disabled subjects. Many of these limitations are based upon the tremendous variety and dissimilarities within the disabled population. Apart from similar hair colour, sex, age, and demographic data, few characteristics among disabled people are easily comparable. It is therefore strongly recommended that future researchers in this field choose a research design that is well-suited to dissimilar populations. Perhaps in the near future, those who study disabled populations will use either a single subject case study or a combination of both the questionnaire format and an interview process. The single subject research design is well designed to accommodate for the many dissimilar physical characteristics and variety of individual sports interests, skill levels, and equipment designs (Watkinson and Wasson, 1985). The use of both a questionnaire and interviews could effectively eliminate missing or inaccurate data. Although this research study boasted a successful pilot study and a remarkable 100 percent return rate, a few subjects had left questions unanswered or answered questions incorrectly. Interviews to the athletes, coaches and sportsmedical support staff would compliment the information reported on the questionnaire's open-ended questions. In this study, the areas most often lacking in complete and accurate data were: injury diagnosis, sports injury treatment, and frequency of injury. For example, the questionnaire section which reported the wheelchair athletes' participation in different sports events was incorrectly completed (Appendix C). Many athletes had reported a sport injury in a sports event for which they had reported zero years of participation or competition. Not only would interviews compliment the information reported on the questionnaires, but would serve to verify the affects of individual style, technique, wheelchair design and ambiguous influences on sports injury occurrence. It is recommended that future researchers using the questionnaire format, administer and collect the questionnaires at the same competition. Their assertiveness would eliminate a plausible low return rate. Although this study had a high return rate, a low return rate could have resulted from mail system delays, subject negligence, or failure to return the completed questionnaires.

The statistical package chosen to analyze the gathered data may be limited by the characteristics of the chosen research design. Apart from single subject case studies, researchers studying disabled populations must overcome the small subject subgroups which negate complex statistical analysis. In a study with many variables, the statistical analysis that is possible is very limited. Basic descriptive statistics calculating the mean, mode, and median are the extent of the analysis. The statistical significance is not great enough, and the controlled variables too few, to allow true cause-effect relationships to be [illegible]. A study with few variables and more controls could lead more advanced statistical analysis. Therefore, it is implied that future researchers using any research design, except single subject case studies, should increase the size of their sample population. The larger categorical subject population would enable statistical calculations of cause-effect relationships within specific subgroups such as disability classifications and particular sports events. Detailed analysis of correlations amongst controlled variables in studies using large sample populations, would lead to statistically significant conclusions.

A final implication from this study future researchers is to use disabled people as subjects in their studies. Customarily, research studies on the disabled population physically or mentally, have used a mixed sample population including varieties of disability types and levels. However, some researchers have used able-bodied subjects in wheelchair sports research in an attempt to limit the study's variables (Hildebrandt et al, 1970; Franklin et al, 1982; Tahamont et al, 1986; Brattgard et al, 1970; Glaser et al, 1978). Brattgard et al (1970) further limited their sample population's gender to control their research parameters. Just as conclusions from scientific animal research do not always coincide with human reality, research on non-disabled subjects may not accurately reflect the characteristics of disabled people.

(ii) Sports Medical Personnel

The primary and most important recommendation to sports medical personnel is to become involved in wheelchair sports. Wheelchair sports is a new and rapidly expanding field. Its growth can be measured not only by athlete popularity, and the increased size of the wheelchair sports support staff, but also by the increased awareness and interest of the general public, and the numerous barriers wheelchair athletes have overcome. These proverbial barriers take the form of world records which are continually shattered by faster times and greater distances, and the physiological barriers which have been surpassed by the courageous and daring efforts of these wheelchair athletes. In earlier years, medical doctors shared a concern for the slow physiological recuperation of quadriplegics after strenuous activities. They declined from encouraging these athletes from competition in the longer track events based on their prediction that these athletes would be very slow to recuperate from physical exertion, if they recovered at all (Goodman, 1986, p. 97). However, these high level spinal cord lesioned athletes are no longer limited to competing in short distance 60 meter track events. As recently as 1985, quadriplegics not only completed longer distance track races, but clocked times of just over two hours (2 hrs 09min 23 secs) in marathons (Alexander, 1985, p. 12).

As times changed, and wheelchair athletes challenged themselves beyond all previous imagination in greater, nobler, and more difficult endeavours, there was a need for the involvement of the sports medical profession. There is a continuuing growing demand for sports medical support staff to contribute themselves, their expertise and their wealth of information to the field of wheelchair sports. Not only is their continued contribution to the scientific literature important, but their excellent practical training in injury prevention, emergency care, injury treatment, and rehabilitation, is essential to the healthy development of Canada's wheelchair athletes, and the careers of the athletic elite.

It is recommended that sports medical support staff clearly document the fitness status of wheelchair athletes. This fitness evaluation could be used as comparative data throughout the sports events' season. Also, regular fitness testing in strength, cardiovascular condition, and anthropometry would increase the number of compiled statistics available to establish fitness norms within each disability class. Recent Canadian research documenting the muscular fitness of wheelchair athletes, based on isokinetic analysis, may soon publish established norms of muscle strength, power, and endurance values for each disability group.

Another implication to the sports medical support staff of wheelchair athletes is to encourage safety in wheelchair sports. Proper design, maintenance and the use of protective equipment and clothing is fundamental to injury prevention. Not only must the equipment fit the athlete's body size, but it should be well constructed, durable, easy to maintain, effective, and relatively inexpensive. Many team sports involve collision type injuries. These collision injuries together with the great speeds attained in sports events such as road racing, would result in less serious injuries if appropriate protective equipment, such as helmets and gloves were worn.

In hot or cold climates the effect weather has on the athlete cam be minimized if appropriate precautions are taken. These precautions include necessary fluid intake and appropriate clothing. Sports medical personnel should be knowledgeable about the physiological temperature regulation limitations of high level spinal cord injured athletes (Appendix H). Thus, as support staff, they are encouraged to monitor these athletes in climatic extremes during training and race events. For example, on days of high temperature and high humidity, the role of the sports medical support staff could include advising race officials to advance their race start time to before sunrise, or after the full heat of the day. Additional roles on race days in hot conditions could be to ensure that the number of water stations, and first aid stations are plentiful throughout the race course and at the finish. Fluid intake is of grave importance in hot, humid race environments, especially to those athletes with altered temperature regulation systems (Appendix H).

In cold weather, perhaps future athletes in winter sports competitions will use temperature sensors in their clothing. These sensors have been tested by Rick Hansen (1986) throughout the winter seasons of his Man in Motion Tour (Hansen, A., 1987). Proven to successfully monitor temperature changes in desensitized, paralyzed limbs, the sensor-laden winter clothing could perhaps eliminate the threat of hypothermia in winter wheelchair sports such as skiing, and sledging. In addition to the threat of hypothermia and hyperthermia, injuries resulting from collisions, pile-ups, flat tires, or mechanical failure of wheelchair parts must be attended to by qualified emergency care personnel. Thus, it is recommended that the sports medical support staff stock all first aid stations, especially at the finish line, with emergency medical care equipment and personnel in preparation for treatment of the various injuries which may have occurred throughout the race course.

(iii) Coach

No longer is it possible for any concerned member of the general population to successfully coach a wheelchair athlete to national or international success. The many characteristics of a successful coach are the very recommendations of this study. It is implied that the coach have technically sound, current information regarding wheelchair sports, athletic performance, training programs, and wheelchair design. It is further implied that the coach have a theoretical understanding of biomechanics, anatomy, exercise physiology, nutrition and fluid intake, proper techniques of stretching, appropriate strength training methods, and basic first aid principles.

The Coaching Association of Canada offers both theoretical and technical levels of coaching. Completion of this basic criteria should be complimented by a vast knowledge base in wheelchair sports. The coach needs to be knowledgeable of specific sports equipment, sports wheelchair design, basic wheelchair maintenance, efficient sports specific techniques, the proper use of protective equipment, and means of injury prevention. The coach must be aware of available training centres for wheelchair athletes' access, where to obtain fitness evaluations for wheelchair athletes, organized teams, sports training camps, competitions, and Games. In addition, the coach must know about current sports information seminars, technical clinics, scientific journals, and other publications. Above all else, the coach needs to be capable not only of comprehension of all of this material, but of its application.

One of the most demanding tasks facing a coach is to set up, for the wheelchair athletes, physiologically sound, individually prescribed training programs. Hopefully, in the near future, research studies will be conducted that will provide substantial evidence regarding the causes of sports injury as influenced by training program protocols. Until these studies appear in the scientific literature, trial and error will continue to dominate the design process of the wheelchair athletes' training program; many athletes and their coaches will continue to believe that the winner's training program is the best.

The coach is also responsible for providing informative feedback to the athletes regarding the analysis of their sport specific techniques or styles. As the athletes' level of success and expertise heightens in a sport, technical errors are no longer blatantly obvious. The small technical corrections are therefore highly refined changes. Often visual feedback, through video analysis, is helpful in the process of identifying and reporting the technique analysis. Video analysis is a useful tool, one which has increased in popularity and use amongst coaches of wheelchair athletes. Other forms of feedback desirable to an athlete include fitness evaluation and sport specific testing. This skill testing could include the athletes' performances in tests of speed, agility, accuracy, and perception.

One last area the coach needs to be familiar with is the psychological preparation of the athletes. Elite athletes often rely heavily upon good mental imagery skills to compliment their fitness and skilled technical ability. Skilled mental imagery involves both the ability to to focus on a task of great importance, and the ability to reproduce the exact atmosphere, attitude and skilled movement sequence of a past victorious performance. How well athletes' focus on their task reflects their ability to interpret and handle pressure situations in sports and influences their final outcome in sports competition. Recently, many able-bodied sports organizations have appointed a sport psychologist to assist their athletes to deal with these obstacles (Monahan, 1987, p. 203). Perhaps, in the near future, national organizing bodies of disabled sports will appoint a sports psychologist to accompany the wheelchair sports teams to elite wheelchair sports competitions.

(iv) Wheelchair Athletes

The primary implication from this study to wheelchair athletes is to lead an athletic career which is relatively free of sports injuries. The statistics of this study reported that the 4 safest sports: sailing, riding, scuba and snooker recorded no injuries. While athletes involved in slalom or riflery reported only one sports injury. The most dangerous wheelchair sport, basketball, had an injury rate of 1.91. One of the most popular sports, track events, were also high (1.12) in injury incidence. Although the team sports of basketball, track, and rugby are amongst the most exciting and popular, the newcomer to wheelchair athletics would have the least chance of sports injury in the individual sports of archery, riflery, slalom, or sailing.

riding, scuba and snooker.

In conclusion are 7 implications from this study to wheelchair athletes who participate, competitively or recreationally in wheelchair athletes. These implications pertain to injury prevention, fitness training, wheelchairs, sports equipment, and the environment.

1. It is implied that wheelchair athletes seek medical advice from available sports medical personnel regarding sports-related injury, its first aid treatment, rehabilitation, and future prevention. Preventitive measures should be taken regarding proper warm-up and regular stretching routines. Athletes may often unknowingly place themselves at risk of sports injury. Athletes who consciously ignore early signs of an injury or omit appropriate warm-up or stretching exercises predispose themselves to sports injury. exercises. Once athletes detect signs of an injury, or require first aid for an injury they should immediately contact sports medical personnel. For elite athletes, injury-free time is crucial. The sports medical support staff member is trained to assist in the treatment and rehabilitation of injured athletes while maintaining the athletes' aerobic conditioning and skill level.

2. To ensure athletes remain in top physical form, they are encouraged to partake in a balanced, personalized yearly training schedule. All athletes must demand from themselves a committment to sports safety and a dedication toward their total body fitness through the practice of sound training regimes. Like all athletes, fit wheelchair athletes can reduce the likliehood of sports-related injury in their wheelchair sports career. Good total body fitness involves sound practices of dietary habits, strength, power, and endurance, low percentage of body fat, and an efficient, well-conditioned cardiovascular system.

3. To limit the development of unnecessary overuse type injuries, the athletes together with their coaches should monitor the training site and surface. The direction of travel both on the track and on the shoulders of deserted roads

should vary. They will want to avoid training on roads where the grade of the shoulders is steep, and preferably train longer distances with equal numbers of corners in each direction (i.e. both directions on a track). Athletes who train on roads should choose those roads which are less busy. The chance of accidents with other vehicles decreases markedly when training takes place on deserted or less frequently travelled paved roads.

4. Fourth, it is implied that wheelchair athletes continue to invest time and energy into the discovery of the most efficient, well-constructed, sport specific, wheelchair designs which ensure proper individual fit. The design of sport specific wheelchairs should continue to ensure proper individual fit according to the variation in body dimensions, to be relatively light, yet durable, and well-suited to the demands of the sports event. The design of the wheelchair must also comply with the rules of wheelchair design specified for each sports event.

5. The fifth guideline for wheelchair athletes is to acquire and wear protective equipment which provides protection against the dangers associated with high speed travel such as helmets, and gloves. Protective equipment and clothing are an important means of injury prevention. Equipment which provides protection against the dangerous injuries associated with high speed travel should be purchased and worn in sports events including road racing, downhill sledge skiing, and wheelchair rugby. Although wheelchair rugby players do not attain the same high speeds as road racers or sledge skiers, they are often 'out of control'. Due to their high lesion level, quadriplegic rugby players have poor balance and a slower hand-eye reaction time. These are a consequence of their general lack of upper limb and postural musculature. Thus to offset their chance of injury, it is recommended that appropriately sized and designed protective equipment be worn.

6. Sixth, wheelchair athletes should dress appropriately for the climate and heed weather restrictions on cold and windy or hot and humid race days. Protective clothing and fluid intake, appropriate to the different climatic conditions of sports events competitions and races, are invaluable in the prevention of the potentially serious conditions of hypothermia or hyperthermia. In addition to the regular human risks of environmental extremes such as, cold, dry weather or hot and humid weather, spinal cord injured people are at a greater risk (Appendix H). In the cold, lack of sensation or movement of extremities hasten the development of the symptoms of frostbite or hypothermia. Lacking temperature regulatory mechanisms, such as shivering, these athletes must use man-made temperature regulation methods. For example, cold sensor body suits, designed by researchers at the University of Victoria, have been successful in monitoring the temperature at several locations in paralyzed extremities. Rick Hansen wore such a successful cold temperature monitoring suit on the wintry days of his Man in Motion Tour throughout 1985 to 1987.

In hot and humid weather, fluid intake and appropriate are equally important. Sufficient fluid intake pre-event and during the competition is essential to maintain the body's fluid level, and to aid in cooling the body. In addition, lightweight, light-coloured, breathable material are characteristics of hot weather clothing appropriate for athletic competition in warmer climates.

7. Finally, the athletes must obtain a coach, sports medical personnel, and access to fitness evaluation. The coach should have the knowledge and expertise to provide technical feedback on sport specific techniques, to arrange regular fitness testing, and to prescribe individually designed, yearly training schedules for all wheelchair athletes. The coach should have an education, interest, and general understanding of sports injury, wheelchair sports and equipment. Access to sports medical personnel who are willing to administer appropriate first aid care and rehabilitation to wheelchair athletes with sports injuries

should be found. Regular fitness testing which monitors wheelchair athletes' muscular strength, endurance, power, cardiovascular condition, and anthropometric dimensions should become the joint responsibility of the coaches, the sports medical staff and the athletes.

(V) Media and General Public

The primary implication to the general public is to become more aware of the accomplishments and potentials of wheelchair athletes. Although it is difficult to objectively measure society's changing attitudes towards disabled people, the public support of wheelchair athletes and their accomplishments is symbolic of society's new attitude. That wheelchair sports exist at the international and Olympic level illustrates the tremendous effect wheelchair sports have had on the lives of physically challenged people.

Many wheelchair athletes are indebted to wheelchair sports for their learned independence and their character development. The experiences gained through sports competition and participation have developed integrity, self-confidence, self-esteem and a greater awareness of the limitless number of activities for disabled participation. Even after their athletic career performances have peaked, many of these athletes remain associated with wheelchair sports fulfilling leadership roles in administration, wheelchair manufacturing, research, coaching, support staff, and always as fans.

The inclusion of international wheelchair sports and Olympic Games for the Disabled is a statement of public acceptance of competitive disabled athletes. Through intense media coverage of disabled sports competitions, personalities, and current research the twentieth century will continue to accept physically challenged people as integrated participants within all walks of life. "Wheelchair athletes have demonstrated that a physical disability need not prevent a person from reaching the pinnacle of excellence" (Crase, 1988, p. 4).

Although wheelchair sports are relatively new, the flashy wheelchair designs, numerous competitors, presence of sports injury, and public support all demonstrate the mechanical, physical, social, and psychological benefits that have resulted.

Mechanically, the innovative wheelchair designs have led to an increased variety of everyday chairs, an improved method of wheelchair sizing, and an increase in the numbers of manufacturers. Wheelchairs can now be measured to each individuals' body dimensions, suited to the demands of each sport, and can be tailored to fulfill individual preferences of colour and comfort. The large number of wheelchair models and sports equipment available to disabled sports enthusiasts is an indication of the challenges undertaken by these individuals. Their positive outlook, character, ideals, values, and attitudes are reflected in the flashy, sporty, dynamic, and colourful sports wheelchairs and sports equipment. Their wheelchairs have become an extension of themselves.

Socially, the interaction between others who are more disabled, or less disabled has encouraged sharing of learned skills and material adaptations or adaptive devices. Competition amongst those of similar disability has encouraged comaradarie and has challenged these athletes to break barriers and exceed previously set limitations.

Psychologically, athletes have developed a positive self-image of themselves through race and sports event victories, and personal achievements in wheelchair sports participation. The independence gained through wheelchairs, modified sports equipment, and the buoyancy of water, together with the unquestioning acceptance of other disabled people, has eliminated many obstacles and barriers. Disabled athletes approach proposed limitations, physical barriers and obstacles with assurance and self-confidence for their successful completion. Over the years, sports have become an integral part of their lives. Now many disabled athletes approach life's obstacles in other avenues with the same energy, enthusiasm, and determination as they met the challenges of sports. Marty Ball, an international wheelchair athlete, noted that the "improvements in self-image and confidence (gained through sports participation) are an important carry-over into everyday life" (Ball, in Duda, 1985, p. 157). The experiences gained through wheelchair sports participation have assisted disabled athletes to prepare and to learn to overcome many similar obstacles and challenges present in other sectors of life.