Original Article

Prevalence of Upper Limb Neuropathy in Rehabilitated Spinal Cord Injured Patients in South India

Bobeena Rachel Chandy[1], Ahana Chatterjee[2], Rohit Bhide[3]

Abstract

Introduction: Paraplegics with spinal cord injury, independent in activities of daily living (ADL) are known to have upper limb neuropathy due to constant use for mobility and transfers. Additionally architectural barriers, disabled unfriendly public transport, difficult terrains and sociocultural barriers in a developing country like India, further adds strain on the upper limbs. Hence, it is important to know the effects of these increased demands in terms of prevalence of peripheral neuropathies in rehabilitated spinal cord injured population from developing countries. In this study we tried to find prevalence of upper limb neuropathy in SCI population in South India.

Methods: Patients with spinal cord injury with a neurological level T2 and below, not having any other associated complication of upper limb due to any other disease apart from SCI were recruited in the study. Total 51 patients (45 male and 6 female) out of 183 patients screened, met key inclusion criteria. All the subjects who were recruited in the study underwent electrodiagnostic studies for the median, ulnar and radial nerves (both sensory and motor). The baseline demographic parameters such as time since injury, age, sex, American Spinal Injury Association scale (AIS), vocation, comorbidities and current mode of indoor and outdoor mobility were recorded. The final diagnosis based on electrodiagnostic study of median/ulnar/radial nerve was graded in scale of 0-2 with 0 being normal, 1 being neuropathy of one hand and 2 being involvement of both the hands.

Results: The scores from demographic data and electrodiagnostic data were accessed and categorical comparison was made between different types of mobility aids and neuropathy (CTS/ulnar/radial). The study showed an overall prevalence of 80% for median neuropathy, 24% for ulnar neuropathy and 16% for radial neuropathy. However, no statistical correlation was found between the use of any particular mobility aid, time since injury, vocation and neuropathy.

Conclusions: We found high prevalence of upper limb compressive neuropathy in the spinal injured population studied, however, due to the small sample size, no statistical significance could be found. We also found carpal tunnel syndrome to be the commonest neuropathy amongst the population especially in the groups that use wheelchair and elbow crutches for mobility.

Key words: **Upper limb neuropathy in spinal cord injury, prevalence, mobility aids *versus* neuropathy in spinal cord injury.**

Introduction:

Upper extremities are primarily designed for prehensile activities. In individuals with spinal cord injury (SCI), they are additionally used for transfers, wheelchair propulsion and daily living activities, putting additional strain on the joints. The cumulative effects of repetitive loading forces can result in joint degeneration and entrapment neuropathies[1]. Since the primary injury itself causes profound changes in lifestyle and limit independence, further complications such as peripheral nerve entrapments can worsen the quality of life further in these individuals [2]. Architectural barriers, disabled unfriendly public transport, difficult terrains and sociocultural barriers in a developing country like India, further limit independence in mobility. This leads to greater strain on the upper extremities compared to their western counterparts.

The prevalence of upper extremity compressive nerve entrapments especially carpal tunnel syndrome (CTS), in chronic spinal injured persons has been shown to

Authors' affiliation:
[1] *MBBS, MD, DNB PMR*
[2] *MBBS, MD (PMR), DNB PMR*
[3] *MBBS, DNB PMR*
Department of Physical Medicine, Christian Medical College, Vellore, Tamil Nadu – 632004

Cite as:
Bobeena Rachel Chandy, Ahana Chatterjee, Rohit Bhide. Prevalence of upper limb neuropathy in rehabilitated spinal cord injured patients in South India. IJPMR, June 2016; Vol 27(2) : 34-40

Correspondence:
Dr. Bobeena Rachel Chandy, MBBS, MD, DNB (PMR), Assistant professor, Department of Physical Medicine, Christian Medical College, Vellore, Tamil Nadu – 632004, E mail: bobeenachandy@gmail.com;bobeenachandy@cmcvellore.ac.in.
Ph.: +91 9894762055

Received on 31/11/2015, Accepted on, 06/01/2016

range from 6.4% to 67 % in the western population. Aljure *et al*[3] in 1985 reported a prevalence of 63 % median and 40% ulnar neuropathy, whereas Davidoff *et al*[4] reported an overall 67% prevalence and Bursell *etal*[5] who studied the largest cohort of patients (502 SCI patients) found a prevalence of 6.4% as the peripheral cause for new onset weakness and/or sensory impairment in rehabilitated SCI patients. The prevalence of cases determined by electrodiagnosis is higher than the number of self reported symptoms [5]. In similar cohorts of disabled patients like amputees and polio survivors, a prevalence of up to 80%[2] has been documented. Literature shows that the two most common peripheral nerve abnormalities (median neuropathy at the wrist and ulnar neuropathy at the elbow) are related to repetitive use like propelling the wheelchair, push-ups and transfers [4, 6].

Hence, it is important to know the effects of these increased demands in terms of prevalence of peripheral neuropathies in rehabilitated spinal cord injured population from developing countries.

Materials and Methods:

Patient with SCI with a neurological level below T2, who were independent in activities of daily living (ADLs), were screened during the annual follow up visit to the Department of Physical Medicine and Rehabilitation (PMR), in this institution. Patients with connective tissue disorders, head injury, documented brachial plexopathy, neck pain and tetraplegics were excluded from the study. All the subjects who were recruited for the study underwent assessment of medical symptoms and general physical examination. The baseline demographic parameters such as time since injury, age, sex, American Spinal Injury Association (AIS) scale, vocation, comorbidities and current mode of indoor and outdoor mobility were recorded.

The electrodiagnostic studies comprising nerve conduction studies of median, ulnar and radial nerves (both sensory and motor) were carried out bilaterally. The standard protocol put forth by the American Association of Electrodiagnostic Medicine[7,8] was followed. Medelec Synergy (VIAsys Healthcare EMG and EP systems, UK Ltd, software version 11) machine was used for the study. The distal latency, conduction velocity across wrist and amplitude was recorded and analysed to diagnose neuropathy if any, in studied nerve. The median, radial and ulnar neuropathy were diagnosed as depicted in Table 1.

Table 1: *Electrodiagnostic Protocol for Diagnosis of Median, Ulnar and Radial Neuropathy* [6, 7]

Diagnostic criteria for median neuropathy at wrist:

- A distal latency in motor component of more than 4.4 ms or a distal latency in sensory component of more than 3.4 ms were considered as positive for CTS
- Difference between the distal motor latency of the median and ulnar nerves >1.1 ms
- Difference between the distal sensory latency of the median and ulnar nerves > 0.2 ms
- Difference between median and ulnar sensory latency on 4th digit stimulation and recording from the wrist at equal distance is >0.4 ms and
- Difference between median and radial sensory latency on thumb stimulation and recording from the wrist at equal distance is >0.4 ms
- Palm wrist conduction: difference between median and ulnar sensory latency across 8cm >0.4ms

Diagnostic criteria for ulnar neuropathy at wrist

- Prolonged wrist to ADM distal motor latency greater than 3.4 ms
- Prolonged wrist to FDI latency greater than 4.5 ms

Diagnostic criteria for the radial superficial sensory branch involvement:

- Amplitude >20.5 µV or/and conduction velocity >64m/s.

The final diagnosis was based on electrodiagnostic study of median/ulnar/radial nerve and was graded in scale of 0-2 with 0 being normal, 1 being neuropathy of one hand and 2 being involvement of both the hands.

The scores from demographic data and electrodiagnostic data were accessed and intergroup comparison (wheelchair *versus* CTS, wheelchair *versus* ulnar neuropathy, wheelchair *versus* radial neuropathy, walker *versus* CTS, walker *versus* ulnar neuropathy, walker *versus* radial neuropathy, tricycle *versus* CTS, tricycle *versus* ulnar neuropathy, tricycle *versus* radial neuropathy, stick *versus* CTS, stick *versus* ulnar neuropathy, stick *versus* radial neuropathy, crutch *versus* CTS, crutch *versus* ulnar neuropathy and crutch *versus* radial neuropathy) was made in order to find the prevalence of upper limb neuropathy amongst users with various mobility aids.

Statistical Analysis:

Data were analysed using the SPSS 17.0 for Windows. The following variables were evaluated as potential risk factors for peripheral compressive neuropathies – vocation, time since injury, use of walker/crutches/wheelchairs/tricycle. Chi- square test for independence and Fisher's exact test was used as a test of statistical significance to analsze categorical variables. P-value <0.05 was considered as statistically significant.

Results:

Of the 183 patients screened, 51 spinal cord injured patients, who were previously rehabilitated at this centre, met the inclusion criteria. Forty-five (88%) out of the 51 patients were males and 6 (12%) were females (Table 2). The mean and standard deviation of age was 39.8 ± 11.2 years. The time since injury showed a median of 8 years (range 1-29 years). Three subjects (6%) had time since injury ≤ 1year, 11 subjects (22%) were between 1and 5 years, 13 (25%) each in the 5-10 years and 10-20 years, while 11 subjects (22%) had injury >20 years (Table 2). Statistical significance of time since injury with the presence of median, ulnar or radial neuropathy was found to be not significant with p-values ~ 0.12, 0.17 and 0.20 respectively.

In this studied population, there were 36 subjects (70%) with AIS A paraplegia, 7(14%) subjects with AIS B, 6 subjects (12%) with AIS C and 2 subjects (4%) with AIS D paraplegia. Of these, 19 persons (37%) were in the T2-T10 category, 27 participants (53%) in the T11-L1 group and 5 (10%) in the L2- L5 group. All the participants were deemed completely independent in all ADL (Table 2).

The vocation of these 51 patients was also taken into consideration. Of the 45 male subjects, 11 (25%) pursed tailoring as their vocation, 2 (4%) were students pursuing bachelor's degrees, 20 subjects (44%) were running their own businesses like teashops, electrical repair and other small establishments, 3 (6%) pursued farming, 1 person (2%) was working as a watchman, and 2 persons (4%) were doing a desk job in offices. There were 6 male subjects (13%) in the group who

Table 2: *Baseline Demographic Data for the Recruited Subjects*

Baseline demographic data	Total (n=51)
Male (%)	45 (88%)
Female (%)	6 (12%)
Age (years) mean ± SD	39.8 ± 11.2
Duration of injury (years) median (range)	8 (1 -29)
Duration of injury:	
≤ 1 year	3 (6%)
Between 1 and 5 years	11(22%)
Between 5 and 10 years	13 (25%)
Between 10 and 20 years	13 (25%)
> 20 years	11 (22%)
Level of injury:	
T2-T10	19 (37%)
T11-L1	27 (53%)
L2-L5	5 (10%)
AIS scale:	
A	36 (70%)
B	7 (14%)
C	6 (12%)
D	2 (4%)
Vocation (male):	
Tailoring (%)	11 (25%)
Student (%)	2 (4%)
Business (%)	20 (44%)
Farming (%)	3 (6%)
Unemployed (%)	6 (13%)
Watchman (%)	1 (2%)
Office work (%)	2 (4%)
Vocation (female)	
Home maker (%)	4 (66%)
Tailoring (%)	1 (17%)
Tuition (%)	1 (17%)

were unemployed. Among the 6 female subjects 4 (66%) were homemakers, one lady (17%) pursued tailoring and 1 lady (17%) took tuition classes for school going children (Table 2).

All the 51 subjects were independent in mobility with a range of mobility aids. There were 25 wheelchair users, 3 walker users, 20 elbow crutch users, 5 subjects using sticks and one subject with a unilateral transtibial amputation using an axillary crutches. Tricycle was being used by 20 participants for independent mobility.

Of 25 wheelchair users the prevalence of CTS was 76% (19 subjects with 13 unilateral and 6 bilateral). In the same group 24% (6 subjects with 5 unilateral cases and 1 bilateral case) had ulnar neuropathy and 16% (4 subjects with 3 unilateral and 1 bilateral cases) had Radial neuropathy. In the category of patients using walker (3 subjects) as their mobility aid, the prevalence of CTS was 100% (1 unilateral and 2 bilateral) and that of ulnar neuropathy was 33% (1 unilateral). There was no radial neuropathy in this group both symptomatically or electrodiagnostically (Table 3).

Table 3: *Tabulation of Electrodiagnostic Findings of Neuropathy in Subjects Using Various Mobility Aids*

Mobility aid (No of users)	CTS		Ulnar neuropathy		Radial neuropathy	
	Unilateral	Bilateral	Unilateral	Bilateral	Unilateral	Bilateral
Wheelchair (25)	13	6	5	1	3	1
Walker (3)	1	2	1	0	0	0
Tricycle (20)	8	8	5	0	4	0
Stick (20)	2	3	1	0	2	0
Crutch (21)	4	13	4	0	4	0

Among the 20 tricycle users, the prevalence of CTS was 80% (16 subjects with 8 unilateral and 8 bilateral), ulnar neuropathy was found to be 25 % (5 unilateral) and radial neuropathy showed a prevalence of 20% (4 unilateral). In the 5 stick users, the prevalence of CTS was found to be 100%, Ulnar neuropathy to be 20% (1 unilateral) and Radial neuropathy to be 40% (2 unilateral). In the crutch users the prevalence of CTS was 81% (17 subjects with 4 unilateral and 13 bilateral) (Table 3).

The overall prevalence of CTS among the 51 subjects included in this study was 80% (41 subjects with 19 unilateral and 22 bilateral cases), ulnar neuropathy was 24% (12 subjects with 11 unilateral and 1 bilateral cases) and 18% had radial neuropathy (9 subjects with 8 unilateral and 1 bilateral cases). 22% (11 subjects) had both CTS and ulnar neuropathy, 16% (8 subjects) had both CTS and radial neuropathy and 6% (3 subjects) had CTS, ulnar and Radial neuropathy. All 3 subjects had a time of more than 10 years since injury.

Eleven SCI patients (23%) were actively pursuing tailoring which involves repetitive hand movements and hence their data were analysed separately. The analysis did not show any significant statistical correlation (Fisher exact test value ~ 1, not significant) with the prevalence of neuropathy but had higher involvement of median nerve neuropathy on comparison to others. As most of the subjects were right handed there was no significant difference in handedness and prevalence of neuropathies.

There was no statistical significant correlation of use of any of the mobility aids with the presence of median, ulnar or radial neuropathy (wheelchair *versus* CTS (p-value = 0.498), wheelchair *versus* ulnar neuropathy (p-value = 1), wheelchair *versus* radial neuropathy (p-value = 1), walker *versus* CTS (p-value = 1), walker *versus* ulnar neuropathy (p-value = 0.561), walker *versus* radial neuropathy (p-value = 1), tricycle *versus* CTS (p-value = 1), tricycle *versus* ulnar neuropathy (p-value = 1), tricycle *versus* radial neuropathy (p-value = 0.724), stick *versus* CTS (p-value = 0.568), stick *versus* ulnar neuropathy (p-value = 1), stick *versus* radial neuropathy (p-value = 0.209), crutch *versus* CTS (p-value = 0.720), crutch *versus* ulnar neuropathy (p-value = 0.743) and crutch *versus* radial neuropathy (p-value = 0.724)).

It was observed based on EMG findings that all the subjects with AIS C and D (motor incomplete)

paraplegia, who were otherwise fairly independent in ambulation and ADLs, had neuropathy. Both the AIS D subjects had bilateral CTS. Of the six AIS C subjects, 5 persons had CTS (4 bilateral and 1 unilateral), one patient had ulnar, radial sensory neuropathy and CTS.

Among the 51 participants, 3 were diabetics. They had well controlled blood sugar level and were on oral hypoglycaemic agents. All three subjects had CTS (2 unilateral and 1 bilateral), 2 subjects had unilateral ulnar neuropathy and one subject had unilateral radial neuropathy.

Discussion:

Persons with paraplegia are dependent on their upper limbs for activities of daily livingADLs, transfers and mobility whether it is wheelchair[6] or walking using orthosis and aids. With availability and awareness of better healthcare facilities, the life expectancy of people with SCI has increased in the past 40 years[9]. This increase in longevity also leads to increase in secondary impairments like overuse injuries to the upper limbs – the shoulders, hands and wrists[10]. The incidence of nerve entrapments due to the repetitive movements at the elbow and wrist and increase in the pressure in the cubital tunnel and the carpal tunnel [6,11], have been implicated for these upper extremity neuropathies. In a developing nation like India, where most public places/services are not particularly wheelchair/disabled friendly, the upper limbs have to be relied upon for home and community ambulation resulting in the development of distal upper extremity mechanical and neurological difficulties which would further compromise their ability to function independently.

Burnham and Steadward[11] in 1994 reported that 19.4% of the 56 arms studied in 28 wheelchair athletes had electrodiagnostic evidence of ulnar neuropathy. The authors had concluded that the entrapment of the nerve possibly occurs at the elbow and the proximal forearm usually at the two heads of the flexor carpi ulnaris. The heavy, repetitive contractions of this muscle lead to the ulnar nerve becoming damaged, entrapped or both. Also another aetiology attributed to ulnar entrapment would be the increase in the cubital tunnel during repetitive flexion and extension at the elbow as well as prolonged pressure on the elbow and proximal forearm when resting against the wheelchair armrest. The population that was studied by Burnham and Steadward[11] were wheelchair athletes. In this study, we noted that of the 25 wheelchair users, 12 persons had ulnar neuropathy. These subjects were all asymptomatic and were electrodiagnostically diagnosed of the neuropathy. The incidence of this was highest among the wheelchair, tricycle and crutch users (5, 5 and 4 subjects respectively with unilateral findings and 1 subject with bilateral findings who was a wheelchair user). However, on statistical analysis, the use of wheelchair and ulnar neuropathy did not show significance in this study. This can be attributed to small sample size.

CTS is one of the commonest nerve entrapments reported by non-spinal cord injured persons. With the presence of disability due to SCI, the upper extremities are used now not only for ADLs but also for mobility and transfers. These activities require repetitive and forceful wrist and hand movements.

Gellman *et al*[6] found that paraplegic subjects had a higher carpal tunnel pressure on wrist extension than did non-paraplegic patients, whether or not they had CTS. They theorised that the increasing pressure during forced extension of the wrist and the repetitive trauma to the volar aspect of the extended wrist whilst propelling the wheelchair may be the cause for the injury. Hence, paraplegic patients with CTS had higher carpal tunnel pressure. Several small sample studies have shown that CTS is a frequent cause of hand pain in SCI patients with a prevalence ranging from 23%-63% [3,4,6]. The prevalence of these neuropathies being determined by electrodiagnosis is higher than the number of self –reported symptoms[12]. In chronic wheelchair users the extremes of wrist extension and wrist flexion enhances the process of degenerative joint changes as well as increases the intracarpal canal pressure, which contributes to development of a median mononeuropathy at the wrist [6,13]. We have focused on the electrophysiological evidence of compressive neuropathies which may have contributed to the higher prevalence as reflected in other reports [11,14]. The other group that was seen to have a high prevalence of CTS were the crutch users. The constant hyperextension of the wrist with weight bearing is implicated for this neuropathy in this group of patients. In this study, the prevalence of CTS among the 51 participants was seen to be 80% with wheelchair users having a prevalence of 76%. However, there was no statistical significance on analysis between the use of any particular mobility aid or vocation to presence of CTS. The study showed that median neuropathy at the wrist was the commonest among the SCI patients.

Vocational rehabilitation is an integral part of SCI rehabilitation. Most of the time, subjects are unable

to pursue their vocation prior to the injury due to inaccessibility caused by architectural barriers, restricted functional abilities, etc, limit their choices in post injury careers. Vocational training for such patients also focuses on jobs/ activities which are mainly deskbound. Tailoring is a common vocation pursued by the persons in the rural part of the country. This may involve repetitive microtraumas and injury which may predispose to compression neuropathy. However, in this study, although no statistical significant difference was observed between subjects pursuing sedentary job against those doing heavy work but there was a definitely higher involvement of the median nerve.

In this study the prevalence of neuropathy in subjects with long term SCI (> 10 years) was not significantly different than other subjects. There was no relationship between the time since injury and the prevalence of compressive mononeuropathy which was also similarly reflected in the study by Stefaniwsky *et al* [15].

In a developing country like India, wheelchairs are often not the best way of mobility due to architectural as well as attitudinal barriers. Hence, SCI subjects increasingly use more than one mobility aid for different purposes. eg, wheelchair use at home and work, knee ankle and foot orthosis along with elbow crutches for access in community and *vice versa*. Paraplegics who have been trained to walk with elbow crutches, usually put excessive pressure at the wrist during gait progression. Analysis of neuropathy in functional elbow crutch users showed greater involvement of the median nerve (81%). Prevalence of ulnar and radial neuropathy was found to be less common in therapeutic elbow crutch users. Twenty-five people in the study population were using more than one orthosis/ mobility aid (eg, elbow crutch and tricycle, walker and tricycle, etc). There was no significant difference in these persons in the incidence of neuropathy as compared to single mobility aid users. From the data collected there seemed to be a definite trend for development of median nerve entrapment and ulnar nerve neuropathy at the wrist due to compression at the Guyon's canal and also at the elbow. Involvement of the radial superficial sensory branch is mostly due to the chronic trauma to the forearm (eg, constricting forearm bands of elbow crutches in paraplegics) or due to repetitive supination-pronation of the forearm. Lesions of the superficial branch of the radial nerve results in a pure sensory syndrome known as Cheiralgia Paresthetica or Wartenberg disease. This branch of the radial nerve becomes subcutaneous as it comes from the posterior border of the brachioradialis and here it is most prone for injury. In this study, 4 of the 9 subjects with sensory radial neuropathy were crutch users, 3 were bed bound and had involvement of the median and ulnar nerves as well and 3 were stick users with consequent ulnar neuropathy too.

Conclusions:

In this study, we found a high prevalence of upper limb compressive neuropathy in the spinal injured population who were included, however, due to the small sample size; no statistical significance could be found. We also noticed that CTS was the commonest neuropathy found in the population especially in the groups that use wheelchair and elbow crutches for mobility.

Though we could not find a statistical significance of time since injury, vocation and use of a particular mobility aid to the prevalence of neuropathy in the upper limb, it is very important to have a high degree of suspicion and look into the modification of the grip style, use of gloves, changing wheelchair to lighter models or ones with a chamber to decrease the effort in propelling the same, body weight control as means of intervention to minimise excessive loading and repetitive trauma to the upper limbs.

Limitations of the Study:

A questionnaire (eg, modified Boston questionnaire) for the subjective assessments of symptoms can be useful for better correlation with the electrodiagnostic findings. This would help with high degree of suspicion, early diagnosis and intervention which would prevent development in further disability. Due to the small sample size no conclusion can be drawn between any of the demographic parameters (such as time since injury, vocation, use of mobility aids, etc) and prevalence of upper limb neuropathy.

Future Directions:

Studies with larger sample size would be able to give a better idea of the prevalence of upper limb neuropathy in this population and also if any demographic aspects had a significant contribution to the development of the same. Also prospective studies can be done to show association body mass index to development of upper extremity compressive neuropathy and competency in wheelchair skills to developing the same.

References:

1. Nemchausky BA, Ubilluz RM. Upper extremity neuropathies in patients with spinal cord injuries. *J Spinal Cord Med* 1995;**18:**95–7.
2. Tsai HC, Hung TH, Chen CC, Lieu FK, Cho H, Tung TH, *et al*. Prevalence and risk factors for upper extremity entrapment neuropathies in polio survivors. *J Rehabil Med* 2009;**41:**26–31.
3. Aljure J, Eltorai I, Bradley WE, Lin JE, Johnson B. Carpal tunnel syndrome in paraplegic patients. *Paraplegia* 1985 ; **23:**182–6.
4. Davidoff G, Werner R, Waring W. Compressive mononeuropathies of the upper extremity in chronic paraplegia. *Paraplegia* 1991; **29:**17–24.
5. Bursell JP, Little JW, Stiens SA. Electrodiagnosis in spinal cord injured persons with new weakness or sensory loss: central and peripheral etiologies. *Arch Phys Med Rehabil* 1999; **80:** 904–9.
6. Gellman H, Sie I, Waters RL. Late complications of the weight-bearing upper extremity in the paraplegic patient. *Clin Orthop* 1988; **233:**132–5.
7. American Association of Electrodiagnostic Medicine, American Academy of Neurology, and American Academy of Physical Medicine and Rehabilitation. Practice parameter for electrodiagnostic studies in carpal tunnel syndrome: summary statement. *Muscle Nerve* 2002 ; **25:** 918–22.
8. Practice parameter for carpal tunnel syndrome (summary statement). Report of the Quality Standards Subcommittee of the American Academy of Neurology. *Neurology* 1993 ; **43:**2406–9.
9. DeVivo MJ, Krause JS, Lammertse DP. Recent trends in mortality and causes of death among persons with spinal cord injury. *Arch Phys Med Rehabil* 1999; **80:**1411–9.
10. Subbarao JV, Klopfstein J, Turpin R. Prevalence and impact of wrist and shoulder pain in patients with spinal cord injury. *J Spinal Cord Med* 1995;**18:** 9–13.
11. Burnham RS, Steadward RD. Upper extremity peripheral nerve entrapments among wheelchair athletes: prevalence, location, and risk factors. *Arch Phys Med Rehabil* 1994 ; **75:** 519–24.
12. Jackson DL, Hynninen BC, Caborn DN, McLean J. Electrodiagnostic study of carpal tunnel syndrome in wheelchair basketball players. *Clin J Sport Med Off J Can Acad Sport Med* 1996; **6:** 27–31.
13. Lundborg G, Gelberman RH, Minteer-Convery M, Lee YF, Hargens AR. Median nerve compression in the carpal tunnel--functional response to experimentally induced controlled pressure. *J Hand Surg* 1982; **7:** 252–9.
14. Yang J, Boninger ML, Leath JD, Fitzgerald SG, Dyson-Hudson TA, Chang MW. Carpal tunnel syndrome in manual wheelchair users with spinal cord injury: a cross-sectional multicenter study. *Am J Phys Med Rehabil Assoc Acad Physiatry* 2009; **88:**1007–16.
15. Stefaniwsky L, Bilowit DS, Prasad SS. Reduced motor conduction velocity of the ulnar nerve in spinal cord injured patients. *Paraplegia* 1980;**18:** 21–4.