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Upper limb function in persons with long term paraplegia and implications for independence: Part I

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The intent of this study was to describe the effects of long term paraplegia and wheelchair use on upper limb function. Bilateral upper extremity isokinetic and grip strength, pain, and active range of motion were compared in 52 men with paraplegia (mean age 44 years; mean duration of spinal cord injury (SCI) 17 years) and 52 age and activity level matched able bodied men. The impact of upper limb pain on activities of daily living (ADL) performance was examined in the paraplegic sample. Strength was not significantly different between the two samples except for bilateral shoulder flexion (able bodied stronger) and bilateral elbow extension (paraplegia stronger). Strength changed similarly with age in the two groups. The effect of duration of SCI on strength, excluding age, was significant for grip strength only. Duration of paraplegia and activity level were better predictors of strength than age in 9 of 14 muscle groups tested, whereas in the able bodied, age was the best strength predictor. Limited bilateral shoulder internal rotation and nondominant external rotation were associated with paraplegia (shoulder $p < 0.001$; elbow $p < 0.001$; wrist/hand $p < 0.001$). Reported pain prevalences for the paraplegic sample were: shoulder 39%; elbow 31% and wrist/hand 40%. The paraplegic subjects' pain intensity ratings revealed them to be experiencing mild to moderate levels of upper limb pain. Shoulder pain was associated with duration of injury, exclusive of age ($p < 0.05$). Measurement of the impact of upper limb pain on 18 activities of daily living tasks revealed pain to be experienced by the majority of subjects with paraplegia (mobility tasks 60%; self-care tasks 58%; and general activities tasks 60%). However, only 23–35% had made changes in their routines, and 6–16% had sought assistance with ADL due to upper limb pain. When age was excluded, it appeared that duration of SCI was more associated with pain during self-care tasks. The tasks most reported to cause upper limb pain were work/school, sleep, wheelchair transfers, outdoor wheeling, and driving. These results suggest that preventative and management steps are required to ensure continued independence and quality of life in this group over time. The effect of duration of SCI suggests that limitations in upper limb function may be seen in this population at relatively young ages.

Keywords: paraplegia; activities of daily living; aging; upper extremity function.

As persons with spinal cord injury (SCI) are now surviving well into later life, the long term effects of wheelchair use are of interest. The performance of daily living activities while in a wheelchair places significant demands on the bones, joints, and soft tissues of the upper limbs. Repetitive activities such as wheeling, transfers, and elevating the shoulders to perform tasks from the seated position in environments designed for persons standing result in marked compression and impulse loads, as well as shearing forces, often in biomechanically weaker ranges of upper limb motion. Previous studies have examined the development of pathology in wheelchair users' shoulders, wrists, and hands.[1–8] A review of this literature has been reported previously.[9] Investigations in the area tend to focus on the shoulders, or wrists and hands, and to report diagnoses or prevalence of pain and degeneration in these regions but not the functional impacts of the pain. A variety of methodologies have been used, ranging from mailed questionnaires, to interviews, to invasive diagnostic procedures. Findings of the studies suggest that upper limb pain and degeneration are indeed characteristic of wheelchair users. However, due to the heterogeneity of samples and methodological approaches, it is difficult to generalize from these studies, or to determine whether the upper limb degeneration is associated more with age or duration of SCI. Further, since the studies did not incorporate able bodied controls or assess performance of activities of daily living (ADL), it is not clear whether the development of upper limb pain and degeneration in the wheelchair user is unusual or to what extent it interferes with daily functioning.

Whether or not upper limb function changes over time more dramatically or earlier in persons with paraplegia than in able bodied people is important to identify in order that these problems can be anticipated and prevented. Furthermore, an understanding of the impact of upper limb function decline on the performance of ADL in paraplegia is essential for treatments and service delivery that will ensure continued maximum independence in this group.

Materials and methods

Data was collected in 1989 in Perth, Western Australia. Fifty-two otherwise healthy men with complete traumatic paraplegia and living in the community, were matched by age and past and present upper limb activity level (exclusive of wheelchair use), to 52 able bodied males. Table I describes the sample. Ethics approval, informed consent, and medical clearance were obtained.

Table II describes and compares the paraplegic subjects' usual activities of daily living practices during the last 6 months by age group (young = < 45 years; old = $\geqslant 45$ years).

The study assessed both physical and performance parameters of upper limb function. Bilateral upper limb physical functions were compared between the paraplegic and able bodied groups on the following parameters: concentric isokinetic average torque for shoulder, elbow flexion/extension, shoulder adduction and eccentric shoulder adduction; grip strength; active range of shoulder and elbow motion; and upper limb pain. Subjects were interviewed using a scheduled format regarding past and present upper limb pain. The impact of upper limb problems on the performance of ADL was measured using a questionnaire that was developed for the study, since no

Table I Description of the sample (n = 52 pairs)

	Paraplegic	Able bodied
Age, mean years (1 SD)	44.3 (12)	44.1 (12)
Height (cm)	147.5 (7)	148.7 (6)
Number living with partner	29	38
Weight, mean kg (1 SD)	71.4 (12)	77.6 (10)
Upper limb activity levels (present)		
Sedentary	38	38
Moderate/heavy	14	14
Duration of spinal cord injury (SCI) in years (1 SD)	17.4 (11)	
Range of SCI duration (years)	1–45	
Lesion levels		
T2-5	10	
T6-10	21	
T11-L2	21	

Table II Comparison of the young and old paraplegic subjects' usual activities of daily living practices

Activity	Paraplegics aged 45 years or less[a] (n = 28)	Paraplegics aged 45 years or more[a] (n = 24)	P value
No. transfers/day in past 6 months	15.0 (6)	14.6 (10)	0.87
No. loading wheelchair to & from car/day in past 6 months	5.1 (4)	1.9 (4)	0.002[b]
No. transfers in & out of bathtub/week in past 6 months	0.0 (0)	0.6 (2)	0.08
No. transfers on & off floor/week in past 6 months	0.8 (2)	0.0 (0)	0.02[b]
Usual wheeling distance in past 6 months			
Mainly indoors	14	17	
Indoors & outdoors & sport	14	7	0.11
Who performed the majority of household tasks in the past 6 months:			
Self or shared	14	5	
Other	14	19	0.03[b]

[a]Mean ± 1 SD. [b]Significance level = 0.05.

instruments designed for this purpose were found. The activities listed in the questionnaire were based on those in the Barthel Index[10] and were modified to suit a wheelchair using population. Content and consensual validity were established through consultation with persons with paraplegia, researchers, and clinicians. The ADL tasks included in the questionnaire are listed in Table III.

Shoulder and elbow isokinetic average torque were measured at 60 °/s and 120 °/s using a KinCom II computer controlled isokinetic dynamometer. The muscle groups tested were selected on the basis of their importance to the performance of daily

Table III Percentage of SCI sample who reported upper limb pain during specific activities of daily living, including overall rank by proportion (n = 52)

Activity	Percent with pain	Overall rank
Work/school	52	1
Sleep	50	2
Toilet transfer	48	3
Bath/shower transfer	48	3
Car transfer	46	4
Outdoor wheeling	46	4
Driving	45	5
Bed transfer	44	6
Retrieve item from shelf above shoulder	37	7
Household tasks	37	7
Indoor wheeling	35	8
Load wheelchair to car	33	9
Hobby/sport	31	10
Outings/social activities	29	11
Dressing	27	12
Grooming	25	13
Bathing/showering	19	14
Bowel and bladder	17	15

activities while in a wheelchair. This was established through a review of the literature and activity analysis using surface EMG on three paraplegic subjects. The protocol and subject stabilization methods were developed specifically for this study since no literature was located that described an upper limb isokinetic strength testing protocol for persons with paraplegia. Prior to proceeding, a separate study ($n = 30$) was conducted to determine the test–retest reliability and this has been reported previously.[11] Reliability of all tests was shown to be very high (intraclass correlation (ICC) range 0.921–0.982).

Data collection consisted of a 1.5 h interview in the home for the paraplegic subjects, plus a 2–2.5 h session in the exercise science laboratory at Curtin University for the physical parameter measurement in all subjects.

Results

Table IV presents a comparison of the upper limb pain reported by the paraplegic and able bodied subjects. Comparative analyses were conducted using McNemar's test for correlated samples. The results suggest that the presence of pain in the upper extremity is clearly associated with paraplegia in men. A comparison of the frequency of reported pain by anatomical region is illustrated in Figure 1. Ten percent of the paraplegic sample was on pain medication at

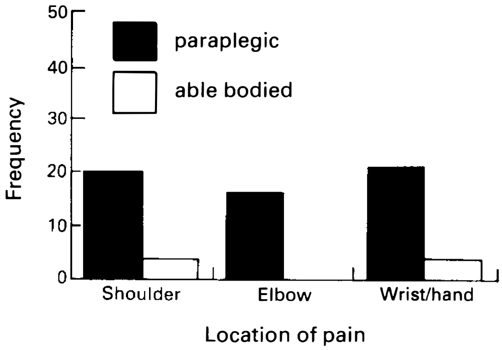

Figure 1 Comparison of the number of paraplegic ($n = 52$) and able bodied ($n = 52$) subjects who reported upper limb pain in the past week.

Table IV Comparison of upper limb pain experienced by the paraplegic and able bodied samples ($n = 52$ pairs)

	Paraplegia (%)	Able bodied (%)	*P* value
Shoulder			
Pain in last week	39	8	< 0.001[a]
Average NRS	4.5	4.0	
Pain in past 6 months	58	27	< 0.001
Frequency	R = 10 I = 31 D = 17	R = 4 I = 19 D = 4	
Elbow			
Pain in last week	31	0	< 0.001
Average NRS	4.0	0	
Pain in past 6 months	39	25	NS
Frequency	R = 0 I = 33 D = 6	R = 8 I = 17 D = 0	
Wrist/Hand			
Pain in last week	40	8	< 0.001
Average NRS	3.5	2	
Pain in past 6 months	60	17	< 0.001
Frequency	R = 4 I = 44 D = 12	R = 4 I = 12 D = 2	

[a]Significant.
R = Rare; I = Intermittent; D = Daily; NRS = Numerical rating scale; 0 = no pain; 10 = worst possible pain.

the time of the study. The majority of the paraplegic subjects reported their shoulder, elbow, and wrist/hand pain to be worst during the day. However, of note was that 20% of the paraplegic subjects experienced their most severe shoulder discomfort while in bed at night.

In an effort to determine whether upper limb pain in paraplegia was associated more with age or duration of SCI, as many pairs as possible were matched for age (within 3 years) and contrasted by duration of SCI (>10 years). McNemar tests showed shoulder pain to be significantly associated with duration of paraplegia, exclusive of age.

Table IV presents and ranks the percentage of paraplegic subjects reporting upper limb pain during ADL. Personal care tasks caused pain least often. Interview data revealed that while 58–60% of the paraplegics reported upper limb pain during some aspect of ADL performance, only 29% had made changes to deal with this, and only 11% had sought assistance with ADL due to upper limb pain. Using matched pairs, it appeared that duration of SCI was associated more than age with pain during ADL, but this was significant ($p < 0.05$) for self care tasks only. Larger paired samples are required to explore this further.

Reduced upper limb range of motion was significantly associated with paraplegia for shoulder internal rotation bilaterally (dominant: $p = 0.01$, nondominant: $p = 0.0005$) and nondominant external rotation ($p = 0.006$). Associations were nonsignificant for bilateral shoulder flexion, abduction, elbow flexion, and dominant shoulder external rotation.

A comparison of upper limb strength scores between the paraplegic and able bodied groups is provided in Table V. Differences were nonsignificant, except for two muscle groups. The able bodied sample was significantly stronger for shoulder flexion by an average of 18% (dominant) and 16% (nondominant). Conversely, the paraplegic sample generated significantly greater elbow extensor torque, on average by 18% (dominant) and 17.5% (nondominant). The same results were obtained when the comparisons were conducted only on subjects aged less than 45 years. In subjects aged greater than 45 years, the able bodied continued to demonstrate significantly

Table V Comparison of upper limb strength between paraplegic and able bodied subjects using the paired t test ($n = 52$ pairs), $\alpha = 0.05$

	Paraplegic mean (1 SD) (nm)	Able bodied mean (1 SD) (nm)	P value
DSF[b]	42.4 (12)	50.1 (10)	0.001[c]
NSF	39.5 (8)	45.7 (10)	0.0003[c]
DSE	44.6 (12)	47.9 (10)	0.162
NSE	43.9 (10)	47.0 (12)	0.173
DEF	48.9 (10)	45.9 (11)	0.085
NEF	45.1 (9)	43.5 (10)	0.395
DEE	40.5 (10)	34.3 (8)	0.0004[c]
NEE	42.3 (9)	36.0 (8)	0.0003[c]
DADC	51.9 (13)	55.8 (14)	0.131
NADC	52.9 (13)	55.2 (12)	0.310
DADE	96.6 (24)	103.0 (26)	0.219
NADE	93.7 (23)	96.8 (20)	0.429
DGRIP	53.3 (9)	50.4 (8)	0.089
NGRIP	48.4 (8)	47.2 (8)	0.519

[a]Newton metres.
[b]D = dominant, N = non-dominant, SF = shoulder flexion, SE = shoulder extension, EF = elbow flexion, EE = elbow extension, ADC = shoulder adduction concentric, ADE = shoulder adduction eccentric.
[c]Significant.

greater shoulder flexor strength, whereas elbow extensor strength differences between the two groups were nonsignificant.

Linear and stepwise maximum regressions were performed in order to assess the effects of age on upper limb strength. The results are shown in Table VI. For the paraplegic subjects, age was a significant predictor of strength in six of the muscle groups tested. However, stepwise maximum regression showed that the best predictors of upper limb muscle strength tended to be factors other than age, such as upper limb activity level, duration of SCI, and lesion level. In the able bodied, age was the best predictor of isokinetic shoulder and elbow strength and upper limb activity level best predicted isometric grip strength.

Chronological age and duration of SCI correlated $r = 0.68$ in this sample. Analyses were therefore performed to determine the effects of each of these two independent variables, independent of the other, on upper limb strength. To do this, able bodied strength values were labelled 'normal'. Then the effect of duration of SCI on strength was examined by plotting the differences in strength between the matched pairs of paraplegic and able bodied subjects against duration of SCI. Similarly, to examine the effects of age independent of duration of SCI, the plots were repeated with paraplegic age on the y-axis. Regression was then conducted. No significant results were obtained.

Discussion

The results of this study suggest that long term paraplegia and wheelchair use are associated with the development of upper limb pain. The proportions of spinal cord injured subjects in this study who reported upper limb pain (shoulder 39%; elbow 31%; and wrist/hand 40%) were consistent with the results of previous investigations.[3–5,12] Despite the high prevalence (60%) of upper limb pain reported by the SCI group relative to the able bodied controls, only 23–35% of the SCI group had made changes in their ADL routines to deal with the pain. Even fewer had sought assistance with daily living tasks (6–16%). There are a number of possible reasons for this. First, pain intensity ratings on average were mild to moderate, rather than severe. Secondly, the group

Table VI The ability of age to predict upper limb strength, and which of age, activity level, lesion level, or duration of SCI best predicted upper limb strength

	Age predict?		Best predictor?	
	Paraplegic	Able bodied	SCI	Able bodied
DSF[a]	0.002[a]	0.009	Age	Age
NSF	0.0005[a]	0.006	Age	Age
DSE	0.32	0.14	Activity	Age
NSE	0.61	0.03	Lesion	Age
DEF	0.03[a]	0.004	Activity	Age
NEF	0.05[a]	0.007	Duration	Age
DEE	0.11	0.05	Activity	Age
NEE	0.17	0.30	Duration	Age
DADC	0.02	0.002	Age	Age
NADC	0.07	0.006	Duration	Age
DADE	0.11	0.03	Activity	Age
NADE	0.27	0.04	Lesion	Age
DGRIP	0.0002	0.07	Duration	Activity
NGRIP	0.002	0.16	Duration	Activity

[a]Significance level = 0.05.
[b](see legend from Table V).

may be stoic or stubborn; viewing the use of assistive devices or assistance as a sign of weakness or giving in. Thirdly, they may not understand the causes of the pain or injury or how to make effective changes. Only a small minority had sought medical attention (< 10%). Many subjects expected that a health care professional's prescription would be either invasive treatment (steroid injections, surgery, hospital admission) or rest. They were fearful of the former and did not see the latter as feasible.

The tasks most commonly reported to elicit upper limb pain (work/school, transfers, outdoor wheeling, driving) are also the activities that allow interaction in the community and are associated with roles that are important for independence and self esteem. Clearly, it is important to minimize the development of upper limb problems in the wheelchair user, both for the individual's comfort and quality of life and for society in general. Upper limb pain that impacts on the wheelchair user's ability to be independent and perform his or her normal roles has implications for society at large in terms of lost productivity and increased health care and attendant support costs, not to mention the impact of increased caregiving on families.

In order to know how and where to intervene, we need to understand how, why, and when upper limb problems seem to develop in this population. Part II of this paper will discuss this aspect further.

Unlike previous studies, our investigation attempted to discern the effects of duration of SCI, independent of age, on upper limb function in paraplegic subjects. The presence of shoulder pain and its interference with ADL performance were both associated with duration of SCI exclusive of age. Gellman *et al*[5] reported similar findings based on frequency distributions, but statistical tests were not reported and age did not appear to have been controlled. The significance of our finding lies in the demographic statistics of traumatic SCI. In the US the majority of traumatic SCIs occur in the 16–20 year old age group (mean age of injury 29.7 years; modal age 19 years).[13] A review of the literature reveals that 15–20 years duration of SCI is usually classified as 'long duration'. Thus, many 'long duration' subjects may indeed be only in their mid-thirties in age. The apparent significant influence of duration of SCI on shoulder pain suggests that even at relatively young ages, persons with paraplegia should be watched closely for the development of overuse related problems. Attention should be directed early to both preventative and treatment approaches.

The significantly greater paraplegic elbow extensor strength versus that demonstrated by the able bodied was not surprising since in the paraplegic subjects this muscle group would be trained frequently when lifting the body weight for wheelchair transfers and ischial pressure reliefs. Perhaps one of the most unexpected findings in this study was the similarity in the vast majority of upper limb isokinetic average torque scores between the paraplegic and able bodied subjects. This may be partly explained by the increased levels of upper limb pain in the paraplegic group. However, all continued to function independently in the community. In the authors' clinical experience, it is often assumed that wheelchair users require more upper limb strength than do the able bodied in order to function independently, and that persons with paraplegia who use wheelchairs develop stronger upper limbs through the training effect of their daily wheelchair activities. The results of this study with regard to the shoulder musculature do not support this assumption, and the significant strength advantage of the able bodied in shoulder flexion is directly opposite to what might be expected. We found similar results when comparing shoulder strength between paraplegic and able bodied women.[9] The literature on kinematics of wheelchair propulsion support our findings. Neither the shoulder extensors or adductors have been shown to play a major role in wheelchair propulsion.[14–16] Cerquiglini *et al*[15] found that shoulder flexor moments generated during wheeling did not exceed 20% MVC at slow speeds and were less than 30% MVC at fast speeds. Harburn & Spaulding[14] reported shoulder flexor MVCs of 40% during wheelchair propulsion. These results suggest that it is not necessary to place heavy emphasis on rehabilitation programs to develop high shoulder strength levels in paraplegic wheelchair users prior to discharge. Endurance and balanced strengthening of the muscles acting around the shoulder may be more critical to independence and the avoidance of injuries and strains.

Conclusions

Based on our research, upper limb pain that interferes with daily function does tend to occur over time in persons with paraplegia. Clinically, the results point to the need to monitor persons with paraplegia regardless of their age, for the development of overuse pathology in the upper limbs. If the upper limbs of those with paraplegia are prone to the development of overuse problems, then wheelchair users whose extremities are already compromised by weakness and muscle imbalance (e.g. quadriplegia, poliomyelitis, degenerative neurological conditions) may be especially at risk. In order to avoid, or minimize and deal with their upper limb pain and maintain their high levels of independence, persons with paraplegia require ergonomically designed environments and equipment; education on the care and conditioning of their upper limbs, and how to manage early signs of strain and overuse; and work simplification and knowledge of a variety of alternative activities of daily living techniques.

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