Spinal Cord (2006) 44, 152–159

www.nature.com/sc

Original Article

Upper extremity musculoskeletal pain during and after rehabilitation in wheelchair-using persons with a spinal cord injury

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Study design: Prospective cohort study.
Objectives: To study upper extremity musculoskeletal pain during and after rehabilitation in wheelchair-using subjects with a spinal cord injury (SCI) and its relation with lesion characteristics, muscle strength and functional outcome.
Setting: Eight rehabilitation centers with an SCI unit in the Netherlands.
Methods: Using a questionnaire, number, frequency and seriousness of musculoskeletal pain complaints of the upper extremity were measured. A pain score for the wrist, elbow and shoulder joints was calculated by multiplying the seriousness by the frequency of pain complaints. An overall score was obtained by adding the scores of the three joints of both upper extremities. Muscle strength was determined by manual muscle testing. The motor score of the functional independence measure provided a functional outcome. All outcomes were obtained at four test occasions during and 1 year after rehabilitation.
Results: Upper extremity pain and shoulder pain decreased over time (30%) during the latter part of in-patient rehabilitation ($P<0.001$). Subjects with tetraplegia (TP) showed more musculoskeletal pain than subjects with paraplegia (PP) ($P<0.001$). Upper extremity pain and shoulder pain were significantly inversely related to functional outcome ($P<0.001$). Muscle strength was significantly inversely related to shoulder pain ($P<0.001$). Musculoskeletal pain at the beginning of rehabilitation and BMI were strong predictors for pain 1 year after in-patient rehabilitation ($P<0.001$).
Conclusions: Subjects with TP are at a higher risk for upper extremity musculoskeletal pain and for shoulder pain than subjects with PP. Higher muscle strength and higher functional outcome are related to fewer upper extremity complaints.
Spinal Cord (2006) **44,** 152–159. doi:10.1038/sj.sc.3101826; published online 6 September 2005

Keywords: pain; upper extremity; shoulder; spinal cord injury; rehabilitation; prospective study

Introduction

Based on epidemiological studies, it seems evident that manual wheelchair propulsion and wheelchair-related daily life activities cause a heavy load on the upper extremities, especially for persons with cervical spinal cord injury (SCI).[1,2] Other suggested risk factors for the development of shoulder pain are the duration of injury, age (ie older people have a higher risk than younger people), higher body mass index (BMI)[3–5] and wheelchair propulsion style.[6] However, research has been limited in terms of methodology and power. Most of the previous studies were cross-sectional and/or retrospective studies and focused on subjects who had a longer duration of the injury. Some of the studies collected data on pain by questionnaires,[7,8] while other studies performed an additional physical examination.[2,3,5] Only few studies looked at complaints that originated during the in-patient rehabilitation.[9–11] Musculoskeletal complaints

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during in-patient rehabilitation can be crucial to the progress and the duration of the rehabilitation.[9] Further, there is not much evidence-based information about the relationship between upper extremity complaints and the functionality of subjects with an SCI.

In the current study, the course of upper extremity musculoskeletal pain over time is described and analyzed in association with the course of muscle strength and functional outcome during and 1 year after rehabilitation. Musculoskeletal pain and functionality are expected to be related since persons with a better physical condition have fewer complaints or less intensive pain.[12]

Knowledge about the course and prognostic determinants of upper extremity complaints is of importance not only to predict the condition of the persons with SCI at the end of the rehabilitation period, but also for treatment and prevention of pain. Timing of more- or less-straining training periods could be beneficial to the occurrence and course of pain complaints.[13]

The aim of this study was to investigate the course of upper extremity musculoskeletal pain and its relationship with lesion characteristics, muscle strength and functional outcome of subjects with an SCI, with special attention to the shoulder joint. Furthermore, the most important predictors for upper extremity musculoskeletal pain 1 year after the rehabilitation were investigated. It is expected that subjects with tetraplegia (TP) have more upper extremity musculoskeletal pain and that subjects with higher muscle strength and higher functional outcome develop fewer complaints.

Methods

Subjects

The present study was part of the Dutch research program 'Physical Strain, Work Capacity and Mechanisms of Restoration of Mobility in the Rehabilitation of Persons with Spinal Cord Injuries'. Persons with an acute SCI were followed during their in-patient rehabilitation and until 1 year after discharge. Subjects were measured four times: at the start of active rehabilitation, defined as being able to sit in a wheelchair for 3–4 h (t_1), 3 months after t_1 (t_2), at the time of discharge from in-patient rehabilitation (t_3) and a year after discharge (t_4). In eight Dutch rehabilitation centers, specialized in the rehabilitation of persons with SCI, a trained local research assistant conducted the measurements, according to a standardized protocol.

Subjects were asked to enter the program if they had an acute SCI, were between 18 and 65 years of age and were classified as A, B, C or D on the American Spinal Injury Association (ASIA) Impairment Scale.[14] Exclusion criteria were progressive diseases, psychiatric problems and insufficient knowledge of the Dutch language. Subjects who were able to walk were excluded from this study, but a small group of subjects with a high lesion level who eventually are using a power wheelchair were included.

For some subjects, the length of stay in in-patient rehabilitation was no longer than 3 months; in these cases, their second measurement was performed at the time of discharge. Data of those subjects were considered as measurements at t_3, meaning that of those subjects no data were available at t_2.

After they had been given information about the testing procedures, the subjects gave their written, informed consent. All tests and protocols were approved by the Medical Ethics Committee of Rehabilitation Centre Hoensbroek, The Netherlands.

Procedure

Lesion and personal characteristics At each test occasion, the lesion characteristics (level and completeness) were assessed by a physician according to the International Standards for Neurological Classification of Spinal Cord Injury.[14] Also the BMI was determined (body mass/height^2).

Pain At the four test occasions (t_1–t_4), the participants were asked in a separate standardized questionnaire if they experienced pain on the joints or muscles of the upper extremity joints, that is, the wrist, elbow and shoulder of both arms. Musculoskeletal pain in each joint was scored as 0 when no pain was present or as 1 when pain was present. Subjects were also asked about the seriousness of pain complaints and about the frequency of pain occurrence. The seriousness was measured subjectively on a Likert scale of 1–5 ranging from very mild to very severe. Frequency was scored as 1 if pain occurred once a week or less, as 2 if pain occurred two or three times a week and as 3 when pain occurred more than 3 times a week.

An overall upper extremity pain score was obtained by multiplying the pain score of each joint by the seriousness and by the frequency of complaints. The scores of the three joints of both upper extremities were added together to obtain an upper extremity pain score, ranging from 0 to 90. The pain score was also analyzed for the shoulder joints separately (score ranging from 0 to 30).

Another section of the survey asked for other (among others neurogenic) pain complaints with specific note about other pain complaints than musculoskeletal pain.

Manual muscle strength To assess the strength of six muscle groups of the upper extremities, standardized manual muscle tests (MMT) were performed for the wrist extensors, elbow flexors and extensors, shoulder internal and external rotators, and shoulder abductors. The MMT for each muscle group was performed in a standardized position.[15] Muscle force was measured subjectively by the research assistant on a scale of 0–5 as follows: (0) no muscle contraction, (1) palpable or visible muscle contraction, (2) active movement through full range of motion (ROM) with gravity eliminated, (3) active movement through full ROM against gravity, (4) active movement through full ROM against resistance, (5) normal muscular strength. The muscle group scores of the right and left upper extremities were added together to obtain an overall MMT score, ranging from 0 to 60.

Functional independence measure motor score The motor score of the functional independence measure (FIM)[16] was used to measure the level of independence in activities of daily living. The Dutch version of the FIM was used for this study.[17] The items were scored on a seven-point scale (1 (completely dependent)−7 (independent)) and the 13 items were added together to obtain an overall FIM motor score, ranging from 13 to 91.

Statistical analyses
Only those subjects who took part in more than one test occasion were included in the analyses. Furthermore, subjects who were community walkers (persons who walk indoors and outdoors possibly with aid and use a wheelchair only for long distances outdoors) at the last test occasion were removed from the database to prevent a positive selection.

To determine whether pain in the upper extremities increased or decreased during and after rehabilitation, the multilevel modeling program MlwiN[18,19] was used. In the longitudinal data set of this study, the hierarchy in the data is the repeated measurement 'test occasion (t_1–t_4)' (level 1), which is grouped within the individual participants (level 2), who are grouped in the rehabilitation centers (level 3). Overall pain in the upper extremity (ranging from 0 to 90) and shoulder pain (from 0 to 30) were the outcome variables of this multilevel regression analysis. Since pain was not normally distributed, this count variable was analyzed with a Poisson model. Time was modeled with three categorical dummy variables, with t_1 as the reference to t_2, t_3 and t_4, for example, the regression coefficient of t_1–t_4 indicated the difference in pain score between t_1 and t_4. *A priori*, time was also modeled with t_3 as the reference to t_1, t_2 and t_4, to examine when significant changes over the time occurred.

To investigate changes in upper extremity pain over time, only the time dummies were included in the basic model.

To investigate the effect of lesion characteristics, lesion level (paraplegia (PP) = 1; TP = 0) and completeness (incomplete = 0; complete = 1) were added to the basic model and a backward regression technique was used (model 2). Personal characteristics (age, gender, BMI) were added to the final model 2 to investigate their effect on the relation between pain complaints and lesion level or completeness. Variables that changed the regression coefficients of lesion level or completeness by at least 10% were identified as confounders and were corrected for in the final analysis. Interaction terms between lesion level and time were also added to check for possible effect modifications ($P < 0.05$). To investigate the effect of muscle strength and motor FIM on pain, these variables were added separately to model 2. These parameters were not put together in the same model since they could have an effect on each other.

To find out which parameters were the most important predictors for pain, a prediction model was set up with upper extremity pain or shoulder pain at t_4 as the outcome variable. Lesion characteristics, personal characteristics, muscle strength and functional outcome at t_1 were used in separate analyses to predict the pain at t_4. Pain at t_1 was a variable that was always added first to the model to account for pain complaints at t_4. First, the independent variables were included separately, and if they showed a *P*-value below 0.1 the variables were added to the Poisson model. Second, a backward elimination technique was used until only significant determinants remained ($P < 0.05$).

Results

Descriptive
A total of 169 subjects participated in this study. The t_1 measurement was performed by 169 subjects. At t_2–t_4, the number of participants was 133, 161 and 116, respectively (Table 1).

The neurological level of the (incomplete) injuries ranged from C2 to S5 (Figure 1). Of the 169 subjects, 20 subjects eventually used a power wheelchair next to their manual wheelchair, whereas seven subjects used only a power wheelchair.

The mean number of days (SD) between t_1 and t_3 was 230 (136) for all subjects, 179 (90) days for those with PP and 309 (157) days for those with TP.

For the parameters muscle strength and motor FIM, the number of subjects who took part in the measurements was smaller and varied over time and over tests. The FIM was scored for almost all subjects while about 20 subjects did not perform the MMTs. The mean

Table 1 Group characteristics

		t_1 (n = *169*)	t_2 (n = *133*)	t_3 (n = *161*)	t_4 (n = *116*)
Lesion	% Paraplegics	59.2	52.6	60.2	66.4
Completeness	% Complete	74.9	69.2	70.3	76.3
Gender	% Male	74.0	75.2	74.5	73.3
BMI ($kg\,m^{-2}$)	Mean ± SD	22.8 ± 3.8	23.1 ± 3.9	23.5 ± 4.0	24.6 ± 4.6

values (SD) of the manual muscle score for the time intervals t_1–t_4 were, respectively, 49.4 (15.1), 50.8 (14.1), 52.9 (12.6) and 55.1 (10.4), and the mean values (SD) for the FIM motor score were 39.0 (19.0), 51.0 (22.5), 61.0 (21.8) and 63.4 (21.2).

Musculoskeletal pain was reported most frequently for the left and right shoulder (Table 2). In addition, subjects with TP reported more complaints in the hand, wrist and elbow when compared to subjects with PP. Pain in all joints was experienced as mild to moderate and occurred three or more times a week. The seriousness and the frequency of the shoulder pain complaints seemed to decrease over time.

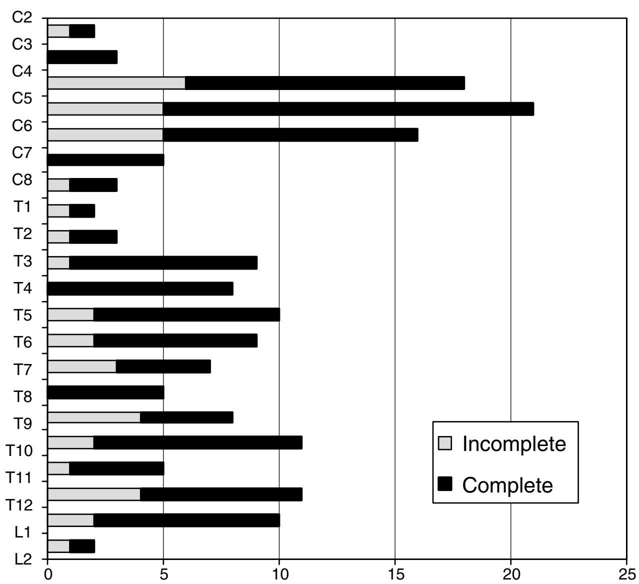

Figure 1 Distribution of level and completeness of the lesion of all subjects at t_1

Course of upper extremity musculoskeletal pain over time and the relationship with lesion level, muscle strength and functional outcome

The basic model, to describe the course of upper extremity musculoskeletal pain, showed a significant reduction in upper extremity complaints ($P<0.001$) between t_2 and t_3 of 30% (Figure 2). There were no significant changes between t_1 and t_2 or t_3 and t_4.

For subjects with TP, the risk of upper extremity complaints was a factor 2.8 higher than for subjects with PP ($P<0.001$) (Figure 2). The interaction terms between time and lesion level showed that subjects with TP showed a stronger decrease in upper extremity musculoskeletal pain than subjects with PP over time intervals t_1–t_3 and t_1–t_4.

None of the personal characteristics were found to be a confounder for the relationship between pain complaints and lesion level over time.

When the parameter 'functional outcome' was added to the model including the time dummies and lesion level, the FIM score was a significant explanatory variable for upper extremity musculoskeletal pain. A 10-point increase of the FIM motor score between subjects and within subjects over a period of time is associated with an 11% decrease in upper extremity pain ($P<0.001$).

Table 2 Descriptive pain data

	Hand wrist		*Elbow*		*Shoulder*	
	Left	*Right*	*Left*	*Right*	*Left*	*Right*
t_1: *PP = 100, TP = 69*						
Complaints PP (*n*)/TP (*n*)	6/20	4/20	9/13	6/13	28/38	28/36
Seriousness (mean ± SD)	2.88 ± 1.21	2.71 ± 1.30	2.91 ± 1.07	2.89 ± 1.37	2.74 ± 1.11	2.66 ± 1.04
Frequency (mean ± SD)	2.69 ± 0.62	2.79 ± 0.51	2.95 ± 0.21	3.00 ± 0.00	2.61 ± 0.70	2.58 ± 0.73
t_2: *PP = 70, TP = 63*						
Complaints PP (*n*)/TP (*n*)	5/16	1/15	4/6	1/5	23/32	22/37
Seriousness (mean ± SD)	2.81 ± 1.12	3.25 ± 1.13	2.70 ± 1.06	3.33 ± 1.03	2.93 ± 1.24	2.76 ± 1.22
Frequency (mean ± SD)	2.70 ± 0.57	2.75 ± 0.58	2.80 ± 0.42	2.50 ± 0.84	2.57 ± 0.75	2.45 ± 0.78
t_3: *PP = 97, TP = 64*						
Complaints PP (*n*)/TP (*n*)	8/9	6/11	4/5	3/8	21/24	21/27
Seriousness (mean ± SD)	3.00 ± 1.19	2.41 ± 0.94	3.00 ± 1.41	2.91 ± 1.22	2.47 ± 1.04	2.55 ± 1.12
Frequency (mean ± SD)	2.72 ± 0.57	2.76 ± 0.56	2.91 ± 0.30	3.00 ± 0.00	2.35 ± 0.87	2.43 ± 0.79
t_4: *PP = 77, TP = 39*						
Complaints PP (*n*)/TP (*n*)	6/8	6/8	3/6	4/10	17/13	20/17
Seriousness (mean ± SD)	2.53 ± 1.26	2.87 ± 0.99	2.80 ± 1.40	2.67 ± 1.29	2.53 ± 1.16	2.28 ± 0.97
Frequency (mean ± SD)	2.40 ± 0.83	2.50 ± 0.85	2.70 ± 0.67	2.33 ± 0.90	2.31 ± 0.82	2.32 ± 0.81

The number of subjects with pain complaints, the mean and standard deviation of seriousness (1–5) and frequency (1–3) of pain per week of the upper extremity joints for subjects with paraplegia and tetraplegia at the four test occasions

Muscle strength was not found to be an explanatory variable of upper extremity musculoskeletal pain.

Shoulder pain

The basic model, to describe the course of shoulder pain, showed that there was a significant increase in total shoulder pain for the time between t_1 and t_2 ($P = 0.018$) and a significant decrease between t_2 and t_3 ($P < 0.001$).

Lesion level had a significant effect on shoulder complaints ($P < 0.001$) and the personal characteristics had no confounding effect. The risk of shoulder complaints was a factor 2.2 higher for subjects with TP than for subjects with PP. In this model, the increase in shoulder pain between t_1 and t_2 was not significant anymore.

The separate analyses of muscle strength and functional outcome showed that both the MMT score ($P < 0.001$) and FIM motor score ($P < 0.001$) were explanatory variables of shoulder pain complaints. A 10-point increase of the FIM motor score led to 14% less shoulder pain and a 10-point increase of the MMT score led to 12% less shoulder pain (Figure 3).

The interaction terms between time and lesion showed again that subjects with TP showed a stronger decrease in shoulder pain than subjects with PP over the time intervals t_1–t_3 and t_1–t_4.

Prognostic model

When the significant univariate variables were combined in a model together with upper extremity musculoskeletal pain at t_1, the BMI and the FIM motor score at t_1 were significant (Table 3) predictors for upper extremity pain at t_4. A 10-point higher FIM score at t_1 was associated with a 10% increased risk on developing upper extremity musculoskeletal pain at t_4 ($P < 0.001$).

For shoulder pain, age, BMI, completeness of the lesion and FIM motor score at t_1 were significant predictors when corrected for shoulder pain at t_1. Except for the completeness of the lesion (78%), the effect on pain was small (<10%). Older persons with a higher BMI, a higher FIM motor score and an incomplete lesion were at a higher risk for developing shoulder pain.

Discussion

Pain is defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage.[20] Not only is pain related to the physical state, but also to the psychological state of the persons. Since pain is a subjective score, and not a physical outcome measurement, it is a difficult variable to work with.

The musculoskeletal pain survey we used in this study was not validated or used in previous studies. As in several other studies. the survey was solely used to ask whether subjects experienced pain. Next to musculoskeletal pain, in a separate section subjects were asked for neurogenic pain at or under the lesion (tight band

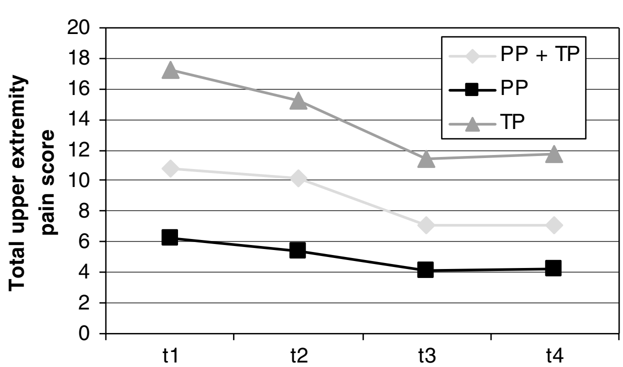

Figure 2 Effect of lesion level on upper extremity pain. Estimation of the total upper extremity pain score for all subjects (based on model 1) and separately for subjects with paraplegia and for subjects with tetraplegia (based on model 2)

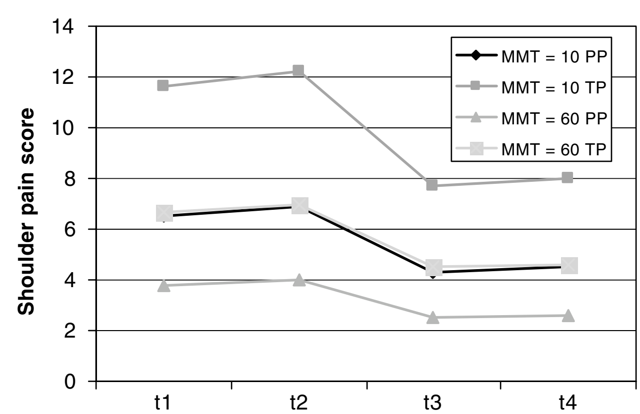

Figure 3 Effect of manual muscle test score on shoulder pain. Estimated shoulder pain score is plotted for a manual muscle score of 10 and a score of 60 for both TP and PP subjects at the four test occasions

Table 3 Results of the Poisson analysis for the prediction of total upper extremity pain score at t_4 with variables at t_1

Variable	*CorrCoef*	*SE*	P-*value*	*IDR*	*95% CI*	*95% CI*
Constant	−0.679	0.213				
Complaints t_1	0.042	0.002	<0.001	1.043	1.039	1.047
BMI t_1	0.064	0.008	<0.001	1.067	1.050	1.082
FIM t_1	0.010	0.002	<0.001	1.010	1.006	1.014

The results are based on the final model after backward elimination
CorrCoef = correction coefficient, SE = standard error of the mean, IDR = incidence density ratio, CI = confidence interval, BMI = body mass index, FIM = functional independence measurement

feeling, phantom pain and dull pain). In this study, it was tried to distinguish musculoskeletal pain from neurogenic pain. It is not always possible to distinguish clearly between these two types of pain and therefore part of the scored musculoskeletal pain could be related to neurogenic pain.

In a large-scale research like the current project, it is impossible to perform physical and technical (MRI) exams at all test occasions. However, for a better analysis of the problem, these exams might be necessary. Therefore, further research would benefit from surveys combined with physical and technical exams.

It has since long been acknowledged that the shoulder joint is especially at risk for overuse injuries due to its complex functional anatomy and its limited muscle mass. The arm is very mobile via the connection to the scapula and its joint structure (a small saucer within a large cup). This mobility goes at the expense of the stability of the joint[21] and makes it especially vulnerable for the development of instability complaints.[22] In the current study, we looked at the development of musculoskeletal pain during and after the rehabilitation process and found that pain complaints develop very quickly, which leads to the conclusion that pain was not simply due to overuse. Musculoskeletal pain could also have developed due to adaptation, in which case pain will probably develop in the long run due to overuse. In this study, the shoulder pain score significantly increased during the first 3 months of active rehabilitation and decreased after that period. Since subjects with SCI in rehabilitation had become dependent on the use of their upper extremities, which are often not well trained in early rehabilitation, training of new skills might have led to stressed muscles and pain. During rehabilitation, when subjects get more experience with arm exercise and had had muscle strength training, pain could diminish. This study showed that the upper extremity musculoskeletal pain score decreased most between t_2 and t_3. It might have been possible that increased independence, more frequent performance of ADL tasks in a less adjusted environment after rehabilitation and less specific muscle training would have led to an increase in pain after the rehabilitation. However, after discharge of in-patient rehabilitation, the musculoskeletal pain complaints did not increase but stabilized.

Lesion level was highly correlated to upper extremity and shoulder pain. This finding was not supported by Dalyan *et al*[8] and Subbarao *et al*,[23] but consistent with Sie *et al*[2] and Turner *et al*.[24] Owing to partial muscle paralysis of thoracohumeral muscles and shoulder muscle imbalance, individuals with high-level SCI are at higher risk of developing musculoskeletal pain.[1,25] It is suggested that muscle paralysis will influence the remaining upper extremity muscles, which have to stabilize the joints and have to produce the necessary external force to perform the task. The subjects with TP also need more external stabilization to maintain trunk balance to perform the task. On the condition that most subjects with a C6 or C7 lesion performed ADL independently, the extra muscle force needed for stabilization could have been responsible for the higher incidence of overload injuries for subjects with higher level lesions. It is possible that shoulder instability, which can arise after muscle paralysis, leads to shoulder complaints, but instability might contribute to the (earlier) onset of complaints due to overuse in subjects with high SCI lesions.

Musculoskeletal pain in SCI is experienced during daily life activities and especially weight-bearing tasks such as transfers and weight relief lifts.[3,23] For these tasks, balance is very important and the net moments and compression forces around the shoulder are high.[26,27] It is common that more than 25% of the body weight is transferred through the humerus to the thorax during the performance of these tasks. Reduction of the subacromial space and impingement of the supraspinatus muscle are possible explanations for the development of pain. However, in this study, all subjects with an acute SCI were included, including seven subjects with a high cervical lesion who had to use a power wheelchair for mobility. Although a small minority group in this study, overload injuries due to manual wheelchair use will not apply to these subjects.

How damage to the joints and the muscles develops is unfortunately unknown, which makes the evaluation of the load on the upper extremity during various ADL one of the utmost importance. More specifically, there is a need for a combined biomechanical epidemiological study, where the dose–response relationship between everyday mechanical load and pain can be studied.

We found that both muscle strength and functional outcome were inversely related to shoulder pain. Subjects with higher maximal muscle forces may perform the ADL tasks at a lower relative force compared to subjects with lower muscle strength. Therefore, these subjects had a lower risk for stress on the muscles. As previously described, higher forces and, as a consequence, higher compression forces in the joint (van Drongelen *et al*, submitted to Clin Biomech) increase the risk on impingement, joint damage and muscle damage. It has been shown[13] that a specific exercise protocol of stretching and strengthening shoulder muscles can lead to a decrease in upper extremity pain. Curtis *et al*[13] found an effect of a 6-month exercise protocol, where the intensity of the experienced pain was decreased. The effect was almost twice as high for subjects with PP than for subjects with TP, reflecting the interaction between functional status and lesion level.

MMT is a fairly crude way to measure muscle strength.[28–30] However, to include a large number of subjects, the MMT data were used instead of the strength data measured with a hand-held dynamometer because the latter were only collected when the MMT score was 4 or 5. In our study, not only the strength of the muscles, which provide the score for the lesion level was measured but the strength of the shoulder internal and external rotators, and shoulder abductors as well. Lesion level will have an influence on the MMT score, but will not necessarily dictate the MMT score since there is variation in the paralysis due to variation in the segment innervation and variation in the completeness of the lesion. From the results, it might be concluded that higher muscle strength would lead to less pain and that exercise could reduce pain complaints.

The FIM motor score can be seen as an indicator of the number of ADL tasks subjects can perform independently. Neurological level of injury will have an effect on the FIM score but will not determine this score, because coordination, skill level, physical capacity and attitude will have an effect on the FIM score as well. Since the FIM motor score is positively correlated to the muscle score,[31,32] it was no surprise that both parameters were explanatory variables for shoulder pain. We expected that subjects with a higher FIM score developed fewer complaints because they have a better physical capacity. However, it was also possible that these subjects with a higher FIM score perform too many ADL and develop complaints as a consequence of overuse, while, on the other hand, subjects with a low FIM score perform fewer tasks and are therefore less susceptible to overuse pain complaints.

In this study, the possibility of having musculoskeletal pain 1 year after the rehabilitation was found to be much higher when pain was already present at an earlier time (t_1). Silfverskiold[10] reported that 33% of subjects with TP who had pain after 6 months still had shoulder pain after 18 months. Therefore, early onset of shoulder pain within 6 months has a high predictive value for pain after 18 months.

Further, BMI, FIM motor score and completeness of the lesion were consistent predictors of musculoskeletal pain in the upper extremity and shoulder. It is not surprising that BMI was found to be a significant variable in the prognostic model, since BMI is obviously related to the amount of physical strain experienced. Heavier persons, due to more body fat or more muscle mass, have a higher mass to transfer and experience a higher drag force during wheelchair propulsion.

It is difficult to relate a higher FIM motor score at the beginning of the rehabilitation to more upper extremity musculoskeletal pain after the rehabilitation, but it is possible that due to their good functionality these persons started performing all sorts of tasks too early while they are generally not aware of the increased risk for upper extremity complaints. They probably have enough strength but they have no experience and are not trained for specific arm function.

The same might be true for the predictor variable completeness of the lesion for shoulder pain. Persons with a complete lesion may perform fewer tasks and have a lower risk on developing pain, while persons with an incomplete lesion are less needy and use less assistive devices with the risk on overload.

Conclusion

The occurrence of upper extremity musculoskeletal pain during in-patient rehabilitation decreased over time. In the studied SCI population using wheelchairs as their primary means of mobility, the reduction in pain complaints was 30% between t_2 and t_3. There was a significant relationship between upper extremity and shoulder pain and lesion level. Subjects with TP were at a higher risk for pain than subjects with PP.

Muscle strength and functional outcome were identifiers for shoulder pain. Higher scores on these tests resulted in 10–15% fewer shoulder pain complaints.

Early onset of upper extremity pain seemed to be the most important predictor of pain at a later time. Thus, in the beginning of the in-patient rehabilitation, one should be very careful to prevent overload (by performing heavy ADL like transfers). The rehabilitation should focus on a balanced training of the upper extremity to make up for the arrears in strength of the upper extremity. Further, overweight should be prevented and one should strive for optimal wheelchair qualities.

Acknowledgements

The work of the research assistants (Annelieke Niezen, Hennie Rijken, Ferry Woldring, Karin Postma, Jos Bloemen, Linda Valent, Sacha van Langeveld and Marijke Schuitemaker) and the rehabilitation physicians is greatly acknowledged. We also thank the eight rehabilitation centers – Rehabilitation Center Amsterdam, De Hoogstraat (Utrecht), Het Roessingh (Enschede), Rijndam Revalidatiecentrum (Rotterdam), Hoensbroeck Revalidatiecentrum (Hoensbroek), Sint Maartenskliniek (Nijmegen), Beatrixoord (Haren) and Heliomare (Wijk aan Zee) – and the subjects for their participation. This study is supported by the Netherlands Organization for Health Research and Development (ZonMW), under Grants 14350003 and 14350010, and is part of the research program 'Physical strain, work capacity and mechanisms of restoration of mobility in the rehabilitation of individuals with SCI'.

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