Spinal Cord (2004) 42, 533–540
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Original Article

Relationship between motor FIM and muscle strength in lower cervical-level spinal cord injuries

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Study design: Retrospective analysis.
Objectives: The objectives of this research were to, in subjects with lower cervical spinal cord injury (SCI), examine the relationship between strength of muscle groups as measured by the manual muscle test (MMT) and function (reflected as burden of care) as measured by individual functional independence measure (FIM) motor tasks, and investigate the extent to which MMT scores explain the variance of the motor FIM scores.
Setting: Acute rehabilitation hospitals, Boston, MA, USA.
Methods: Retrospective pilot study of 20 in-patients, age 18–62 years, with an SCI between C5 and C7. Discharge demographic variables, MMT and motor FIM scores were analyzed. Descriptive statistics, Spearman's rank correlation coefficients, stepwise regressions were performed.
Results: MMT scores for elbow flexion followed by shoulder flexion and wrist extension correlated with the greatest number of FIM tasks. MMT scores explained some part of the variance in the eight of 12 motor FIM tasks. In six of eight tasks, one key muscle explained a large portion of the variance.
Conclusion: Key muscles relative to FIM tasks can be identified. These findings may help focus therapeutic interventions aimed at achievement in these tasks.

Spinal Cord (2004) **42,** 533–540. doi:10.1038/sj.sc.3101635; Published online 29 June 2004

Keywords: functional independence measure; manual muscle test; impairments; rehabilitation; spinal cord injury; tetraplegia

Introduction

Approximately 200 000 individuals in the United States are estimated to have a spinal cord injury (SCI).[1–3] Cervical spine injuries, accounting for approximately 50% of all cord injuries,[4] result in extensive impairments, functional limitation, and disability.[4–6] The level and severity of injury determine the type and degree of impairments and functional ability. The strength of certain key muscles or muscle groups can contribute to functional capabilities of the individual.[1,6]

In recent years, the models proposed by Nagi[7] and the Institute of Medicine[8] have provided a helpful framework in understanding the relationship of impairments to functional limitations.[7,9] In Nagi's disablement model,[7] impairment is defined as abnormality at the tissue, organ, or body systems level, and functional limitation is the restricted ability to perform daily activities. In patients with SCI, the primary impairment is muscle weakness or paralysis resulting in limitations in performing a variety of functional tasks. Primary objectives of the rehabilitation effort are to maximize the available muscle performance and teach new skills in order for the patient to achieve full functional capabilities. When considering the allocation of resources to maximize the benefit of rehabilitation, a fuller determination of the extent to which key muscle groups contribute to the performance of functional tasks would be useful. Interventions could then be more precisely directed toward key muscle groups related to a task in order to optimize outcomes.

Two clinical measures widely used to identify impairment and function are the manual muscle test (MMT) to measure strength and the functional independence measure (FIM) to assess the burden of care during functional tasks. Face and content validity of MMT are high,[10] and intertester reliability in patients with SCI is excellent ($r = 0.94$).[11] However, Noreau and Vachon[12]

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have indicated that MMT is not sensitive enough to distinguish between increments at higher levels of strength or to detect the small or moderate increases seen in patients with SCI. Despite these limitations, MMT is the clinical measure most utilized to examine strength in the SCI population.[13]

The FIM was developed to assess a wide variety of disabilities[14] and is widely used in rehabilitation settings. It has good face and content validity,[14] excellent concurrent validity,[15] and good-to-excellent ($r = 0.81$–0.96) inter-rater and intrarater reliability.[15–17] Questions have been raised regarding the FIM's sensitivity to critical functional changes in the SCI population.[18–21] Others have suggested that the FIM may not be the optimal tool to measure functional abilities due to its design as a measure of burden of care.[20,21] This has resulted in the development of other tools to measure function such as the Spinal Cord Independence Measure,[22,23] the Quadriplegia Index of Function[24–27] and the Spinal Cord Injury Realization Measurement Index (SCI-ARMI).[20,21] Despite these limitations, the FIM is the most widely used measure of functional limitation for the SCI population during rehabilitation[6,13] and is accepted by the American Spinal Cord Injury Association (ASIA).[13]

The relationships between level of injury, strength and function have been studied from different perspectives. Several investigators[28–33] have explored the relationship between the level of injury and predicted motor recovery finding that lower functioning neurological levels are associated with greater motor recovery. Others[1,34–36] have established expected functional outcomes associated with neurological levels. The paralyzed veterans of America (PVA) related injury level to functional limitation as reflected in performance of motor FIM tasks.[6] Middleton *et al*[18] examined the relationship between neurological level and individual motor FIM tasks at discharge from rehabilitation. They found an expected pattern of increasing FIM scores with more caudal neurological levels with the exception of locomotion and stairs. Marino *et al*[37] compared motor level with neurological and sensory levels in their ability to predict self-care function in subjects with tetraplegia. They found that motor level is superior to neurological and sensory levels in determining the relationship with functional tasks due, in part, to the large variance of motor scores at a given neurological level. Further, they stated that while motor level is a better predictor of self-care function than neurological level, the key muscle at a given motor level (as defined by ASIA[13]) may not necessarily be responsible for the improved function. The contributions of critical muscles needed for specific tasks have yet to be clearly defined. Analyzing by level, whether neurological or motor, can render important information for predicting outcome but does not necessarily identify the relative contributions of muscle groups to the completion of various tasks.

Two studies[38,39] have examined specific relationships between muscle performance and functional abilities. Welch *et al*[38] reported the critical levels of strength in key muscle groups relative to independence in certain functional activities. Subjects with 3+ MMT scores in triceps were more independent than those with less than a 3+ score. Fujiwara *et al*[39] related a sum score of scapular and shoulder strength to the total motor FIM score and the specific FIM task of bed to wheelchair transfer. They found excellent correlations between scapula/shoulder strength sum score and these two FIM scores. While these studies have further explained the relationship between muscle performance and functional activities the specific contributions of strength to the individual FIM tasks has not been reported.

Therefore, the purposes of this pilot study were to examine the relationships between impairments of strength as measured by MMT and functional limitations as measured by the individual FIM motor tasks in subjects with a lower cervical-level SCI (C5–C7) and to explore the extent to which the MMT scores explained the variance in the motor FIM scores. If the results of this exploratory analysis were fruitful and the relationship between specific muscle strength grades and individual motor FIM scores could be determined, a more complete investigation would be warranted.

Methods

Subjects were in-patients at Spaulding Rehabilitation Hospital or at Boston University Medical Center, Boston, MA between 1995 and 2002. We certify that all applicable institutional and governmental regulations concerning the use of human volunteers were followed during the course of this research. This pilot study was approved by the Institutional Review Boards of Boston University Medical Center and Spaulding Rehabilitation Hospital. Inclusion criteria included a lower cervical SCI (C5–C7) as the primary diagnosis resulting in complete or incomplete tetraplegia, proficiency in English, and admission to rehabilitation within 1 year of initial injury. Excluded were individuals with a traumatic brain injury or orthopedic or medical diagnoses other than the neck injury that would affect function at discharge. To limit the analysis to subjects who would rely on the upper extremities for completion of functional tasks, subjects with incomplete injuries with abdominal or lower extremity MMT scores greater than 2 out of 5 were also excluded.

Patient information was obtained from an SCI database and medical records. Demographic variables acquired included gender, age, ethnicity, marital status, level of injury, injury onset date, ASIA scale,[13] admission and discharge dates, length of stay (LOS), facility admitted from, pre- and posthospital living arrangements and employment status.

Discharge impairment and functional scores were recorded. The MMT was performed by the primary physical or occupational therapist and standardized by the Daniels and Worthingham method.[40] No information was available on patient positioning or stabilization during testing. The muscle scores analyzed included shoulder, elbow and wrist flexion and extension. These muscles were chosen based on clinical relevance and available data. Scores were transformed by adding 0.25 for a plus score and subtracting 0.25 for a minus score. For example, scores of 2+ and 3− were converted to 2.25 and 2.75, respectively.

Individual motor FIM scores were analyzed. No subject was able to ambulate; therefore, the locomotion score represents wheelchair propulsion and the stair task was eliminated. Information was not available as to whether wheelchair mobility represented power or manual wheelchair propulsion.

The data were analyzed using SPSS 10.0 Statistical Software for Windows[41] (SPSS Inc., 233 S. Wacker Dr, Chicago, IL, USA). Descriptive statistics (frequency and/or mean, median, standard deviation, and range) were determined for all variables. Descriptive statistics for the FIM scores were calculated for the whole sample and by injury level. Subjects were categorized based on whether they were dependent as indicated by FIM score of 1 or 2, modified independent indicated by a FIM score of 3–5, or independent with an FIM score of 6 or 7. Spearman's rank correlation coefficients were calculated among MMT scores. Right and left MMT scores were significantly correlated with the exception of shoulder extension (Table 1). Power analysis performed according to methods described by Portney and Watkins[42] revealed that correlations between the right and left sides had a power level of 0.98 at the $P<0.05$ level except for shoulder extension, which had a power level of 0.23. Therefore, to avoid confounding further analysis, only the right-side MMT scores were entered into further calculations except for shoulder extension where the right and left MMT scores were entered separately. Correlations were then determined between seven MMT scores and the individual motor FIM tasks.

Table 1 Spearman's rank correlations of right *versus* left MMT scores

Muscle test	r *value*
Shoulder flex	0.71*
Shoulder ext	0.36
Elbow flex	0.86*
Elbow ext	0.97*
Wrist flex	0.82*
Wrist ext	0.73*

*Significance at $P<0.01$ level
flex = flexion; ext = extension

Stepwise linear regression analyses were conducted to determine how much of the variance in motor FIM tasks could be explained by MMT scores. All seven MMT scores were entered as independent variables.

Results

Of the 20 patients analyzed, 16 (80%) were male and four (20%) were female. Age at admission ranged between 18 and 62 years. The mean age was 36.8 years (SD = 13.4) and the median age was 36 years. In all, 95% were white and 5% Hispanic; 50% single, 35% married, 10% divorced and 5% separated. The most common injury level was C6 ($n=11$, 55%), followed by C5 ($n=7$, 35%) and C7 ($n=2$, 10%). In total, 65% were classified as ASIA A, 30% as ASIA B, and one patient (5%) was diagnosed with anterior cord syndrome. Only two (10%) subjects had motor function below the level of the lesion with MMT scores no greater than 2. Length of stay varied from 29 to 266 days (mean = 97.65; SD = 71.02). A majority of the patients were admitted from acute care facilities (85%); all others were transferred from the acute care section of the same facility (15%). Prior to injury, patients were living at home with family (70%), with friends (20%) or alone (10%). In all, 75% were employed, 10% were students, and 15% were homemakers, unemployed, or retired. Upon rehabilitation discharge, 80% went home with family, 10% went to a skilled nursing facility, and 5% went to an assisted living facility. Discharge placement for one subject could not be determined. No one went home to live alone.

The means, medians, standard deviations, and ranges of the MMT scores are presented in Table 2. Elbow

Table 2 Descriptive statistics of the MMT scores

Muscle test	n	*Mean*	*Median*	*SD*	*Range*
Shoulder flexion R	20	3.7	3.75	0.81	2.25–5
Shoulder flexion L	20	3.6	3.87	0.99	1.75–5
Shoulder extension R	11	3.5	3.75	0.98	1.75–5
Shoulder extension L	12	3.7	3.50	1.05	2.25–5
Elbow flexion R	20	4.4	4.25	0.53	3.25–5
Elbow flexion L	20	4.4	4.25	0.72	2.75–5
Elbow extension R	19	2.1	2.00	1.66	0–5
Elbow extension L	19	2.0	2.00	1.73	0–5
Wrist flexion R	14	1.5	0.00	1.90	0–5
Wrist flexion L	14	1.4	0.00	1.92	0–5
Wrist extension R	20	3.4	3.50	1.40	0–5
Wrist extension L	20	3.1	3.50	1.63	0–5

R = right; L = left; SD = standard deviation flexion had the highest MMT scores and wrist flexion had the lowest. Correlations among MMT scores are shown in Table 3. As expected MMT scores of muscles related by neurological level were highly correlated with each other. For example, shoulder flexion, elbow flexion and wrist extension are all highly correlated and are all related to the C5–C6 neurological levels. Likewise, elbow extension and wrist flexion were also highly correlated and both are related to the C7 neurological level.

Scores for the motor FIM tasks for the whole sample and by neurological level are presented in Tables 4 and 5, respectively. The highest FIM scores for the whole sample were for locomotion (wheelchair) and eating. The lowest score was for bowel management. Independence was reached by subjects in eating (20%), grooming (15%), bladder management (5%), and locomotion (45%; wheelchair).

The correlational relationships between the MMT scores and the FIM tasks are shown in Table 6. Elbow flexion was related to the greatest number of FIM tasks (10 of 12) followed by shoulder flexion (eight of 12) and wrist extension (seven of 12). The strongest relationships were between left shoulder extension to bladder management, elbow flexion to toileting, shoulder flexion and right shoulder extension to dressing upper body, and wrist flexion to toilet/tub/shower transfers. The weakest significant relationship was between shoulder flexion and dressing lower body. No significant correlations were found between any muscle group and locomotion (wheelchair).

The results of the stepwise regression are presented in Figure 1 showing the specific MMT scores that partially explained the variance in eight of 12 motor FIM tasks.

Table 5 Median FIM scores by injury level

FIM task	*C5* (n=*7)*	*C6* (n=*11)*	*C7* (n=*2)*
Eating	5.0	5.0	5.0
Grooming	4.0	4.0	5.0
Bathing	2.0	3.0	3.0
Dress upper body	2.0	4.0	4.0
Dress lower body	1.0	1.0	3.5
Toileting	1.0	1.0	4.0
Bladder management	1.0	1.0	4.0
Bowel management	1.0	1.0	1.5
Transfer bed to WC	1.0	2.0	4.5
Transfer to toilet	1.0	1.0	4.0
Transfer to shower/tub	1.0	1.0	3.5
Locomotion (WC)	6.0	5.0	5.5

WC = wheelchair

Table 3 Spearman's rank correlations of MMT scores

	Shld flex	*Shld ext R*	*Shld ext L*	*Elbw flex*	*Elbw ext*	*Wrist flex*
Shld ext R	0.82**					
Shld ext L	0.42	0.36				
Elbow flex	0.74**	0.73**	0.39			
Elbow ext	0.60**	0.77**	0.40	0.58**		
Wrist flex	0.46	0.50	0.27	0.50	0.91**	
Wrist Ext	0.68**	0.83**	0.35	0.83**	0.74**	0.66*

*Significance at $P<0.05$ level
**Significance at $P<0.01$ level
Shld = shoulder, Elbw = elbow, flex = flexion, ext = extension

Table 4 Descriptive statistics of the motor FIM tasks ($n=20$)

FIM task	*Mean*	*Median*	*SD*	*Range*	*FIM score 1–2* (n)	*FIM score 3–5* (n)	*FIM score 6–7* (n)
Eating	4.7	5	1.17	1–6	1	15	4
Grooming	4.1	4	1.39	1–6	2	15	3
Bathing	2.5	2.5	1.00	1–4	10	10	0
Dressing upper body	2.9	2.5	1.50	1–5	10	10	0
Dressing lower body	1.5	1	1.00	1–4	18	2	0
Toileting	1.8	1	1.20	1–5	15	5	0
Bladder management	2.0	1	1.79	1–7	16	3	1
Bowel management	1.4	1	0.94	1–5	19	1	0
Transfers bed to chair	2.2	2	1.44	1–5	14	6	0
Transfer to toilet	1.7	1	1.27	1–5	17	3	0
Transfer to shower/tub	1.6	1	1.14	1–5	17	3	0
Locomotion (WC)	4.9	5	1.52	1–6	2	9	9
Stairs	1.0	1	0.00	1–1	20	0	0

WC = wheelchair; SD = standard deviation

Table 6 Spearman's rank correlations between MMT scores and motor FIM tasks

FIM task	*Shld flex*	*Shld ext R*	*Shld ext L*	*Elbw flex*	*Elbw ext*	*Wrst flex*	*Wrst ext*
Eating	0.49*	0.20	0.55	0.68*	0.11	0.02	0.41
Grooming	0.33	0.11	0.04	0.48*	0.33	0.04	0.30
Bathing	0.56*	0.31	0.51	0.62*	0.44	0.34	0.52*
Dress upper body	0.72*	0.71*	0.40	0.66*	0.66*	0.48	0.64*
Dress lower body	0.45*	0.48	0.50	0.68*	0.67*	0.67*	0.63*
Toileting	0.55*	0.41	0.40	0.75*	0.57*	0.56*	0.60*
Bladder management	0.33	0.69*	0.76*	0.52*	0.31	0.13	0.40
Bowel management	0.22	0.47	0.59*	0.40	0.18	0.00	0.30
Transfer bed to chair	0.50*	0.56	0.38	0.62*	0.60*	0.58*	0.56*
Transfer toilet	0.48*	0.44	0.45	0.58*	0.69*	0.73*	0.62*
Transfer shower/tub	0.49*	0.44	0.45	0.58*	0.69*	0.73*	0.62*
Locomotion (WC)	−0.08	−0.13	−0.21	0.25	−0.10	0.03	0.00

*Significance at $P<0.05$ level
Shld = shoulder; Elbw = elbow; Wrist = wrist; flex = flexion; ext = extension; WC = wheelchair

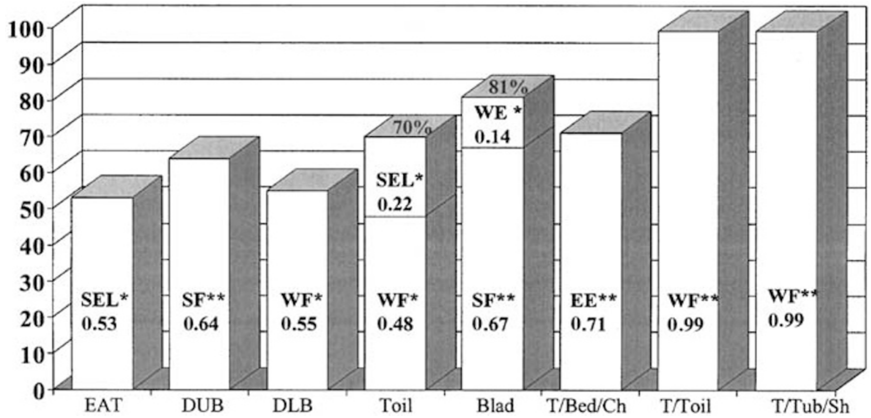

Figure 1 Stepwise regression analysis by FIM task. *Significance at $P<0.05$ level. **Significance at $P<0.01$ level. SEL = shoulder extension left; SF = shoulder flexion; WF = wrist flexion; EE = elbow extension; WE = wrist extension; EAT = eating; DUB = dressing upper body; DLB = dressing lower body; Toil = toileting; Blad = bladder; T/Bed/Ch = transfers bed to chair; T/Toil = transfers to toilet; T/Tub/Sh = transfers to tub and shower

Toileting and bladder management were the only two tasks where two variables contributed to the explanation of the variance of the score. None of the strength measures studied explained any part of the variance for the FIM tasks grooming, bathing, bowel management, and locomotion (wheelchair).

Discussion

The primary objective of this pilot study was to relate the MMT scores to individual FIM tasks in patients with C5–C7 SCI. In this exploratory analysis, relationships between muscle strength as measured by MMT scores and individual motor FIM tasks were identified. Additionally, through regression analysis the specific contributions of key muscle groups to the performance of FIM tasks were more clearly delineated.

Overall, elbow flexion was correlated to the greatest number of FIM tasks indicating its participation in a variety of tasks. The strength of elbow flexion, shoulder flexion and wrist extension strength were significantly correlated to the same seven FIM tasks, which may suggest that they are inter-related in the performance of those specific tasks. The relationship of muscle strength to function as measured by the FIM scores was further understood by explaining the variance of the FIM scores by the variance of the MMT scores. Single MMT scores were found to explain large portions of the variance of eight FIM tasks suggesting that individual muscles may be key to certain tasks. Despite our small sample size, the regression analyses generally confirmed the findings of the correlational analyses with muscle groups correlated with specific task also entering in the regression equation for that task.

Welch *et al*[38] explored the importance of 3+ MMT scores in wrist extension and elbow extension to independence in a variety of activities. Although these muscles may be important in selected tasks, our findings suggest that elbow flexion and shoulder flexion are moderately or strongly related to more FIM tasks than are wrist or elbow extension. Furthermore, based on the correlation results elbow flexion and elbow flexion combined with shoulder flexion seemed critical to completing the tasks of grooming and eating, respectively.

Elbow extension strength strongly correlated with all three FIM transfer tasks and explained 71% of the variance of the bed to transfer score. This corroborates clinical findings and those of Welch *et al*,[38] who demonstrated the importance of 3+ elbow extension strength in bed to chair transfers. In the present sample, wrist flexion explained a large percentage of transfers to toilet and tub/shower. Patients with active wrist flexion had low MMT scores (mean = 1.5) and 15–17 of 20 subjects required total assistance with those two transfer tasks. This clustering of low FIM and low MMT scores seemingly accounts for this strong relationship. Analysis of a larger sample with greater variance in MMT and FIM scores would provide a better understanding of the contribution of wrist flexion strength to these tasks.

Fujiwara *et al*[39] found a very strong correlation between a scapular/shoulder muscle sum score and the FIM bed to chair transfer score. In our analysis, we did not find that shoulder extension as a single muscle group related to transfers suggesting that the relationship of shoulder extension to transfers may be revealed only in a sum score. These findings should be viewed with some caution, however, as few subjects had recorded right ($n = 11$) and left ($n = 12$) shoulder extension MMT scores. There exists the possibility that a Type II error was committed. We suspect that shoulder extension may have correlated significantly had the number of subjects been larger.

Bowel management had the lowest mean score with 19 of 20 patients dependent in the task and was correlated only with left shoulder extension. These findings are consistent with the clinical finding that bowel management is a very challenging task for these patients often requiring the use of suppositories or digital stimulation as part of a regular bowel program.[1] Success at this task would require considerable strength and dexterity, and was beyond what these subjects could perform at discharge.

No correlation was found between MMT scores and the locomotion (wheelchair) task. This is likely due to the scoring mechanism for the FIM where no distinction is made between manual and motorized wheelchair propulsion. Distinguishing between means of wheelchair propulsion would not be critical within the FIM design since a similar score for either means of wheelchair propulsion would indicate the same burden of care.[14,23] However, the physical abilities required to perform propulsion by the different means are, of course, quite different. Relevant to the present pilot study, this scoring also makes it impossible to determine the relationships between muscle strength and the wheelchair task.

In order to determine how this pilot group was compared with a larger sample, we also compared median motor FIM scores by neurological level of the patients in our sample to those scores reported by the PVA.[6] A majority of the median FIM scores were similar. Compared to the PVA population, our scores differed by no more than one FIM level except on two tasks where our patients had scores two levels higher. These tasks were grooming for patients at C5 and bathing at C6. The patients with a C7–C8 injury in the PVA study had one level higher FIM scores in eating, grooming, and bathing. The PVA study combined patients at the C7 and C8 levels, which may account for these differences. Additionally, the PVA reported scores up to 1 year postinjury compared to our scores reported at discharge from rehabilitation, which was within 9 months of onset. Welch *et al*[38] demonstrated that improvement continues from discharge to 1 year postinjury. Similar to our findings, Middleton *et al*[18] found subjects to be most dependent in bowel management. Of the self-care items, patients were most independent in eating and grooming and were most dependent in toileting. Of the mobility items, patients were less dependent in bed transfers than they were in toilet or tub transfers.[18] The similarity of FIM scores across the PVA[6] study, Middleton *et al*[18] and our subjects indicate that our sample was representative of a larger sample. Gender distribution,[3,4] marital status,[4] LOS,[43] and mean age at injury onset[3,4] were similar to those in the literature; however, the median age was older by 10 years (60% >36 years).[4] Length of stay in our sample had a large range due to three subjects with LOS longer than 200 days due to complications. The most common SCI level in our sample was C6 *versus* C5 found in other studies.[4,44] In all, 95% of our patients were White, which was higher than the norm, but the proportion of Hispanic patients was similar to the literature.[3,4,45] Previous employment status was higher for our patients (75%) compared to the literature (63.6%),[3] which may have been related to their older age as was discharge to home (92%).[3]

The purpose of excluding subjects with greater than 2+ MMT scores below the lesion level was to assure that the sample was limited to subjects with complete or nearly complete tetraplegia who would primarily use their upper extremities for the completion of tasks. Consequently, potential subjects with central cord lesions were excluded. As these patients would have wrist and hand muscles stronger than proximal shoulder muscles, their method of accomplishing these tasks may be significantly different from the current sample and our findings should not be extended to this patient group.

Clinically, our results are useful in more specifically determining the relationship between muscle strength and functional tasks. This information can be applied to intervention planning such that therapeutic exercise programs emphasize key muscles related to specific tasks and may suggest considerations for exercise intensity. For those tasks where the relationship with specific muscle groups has not been identified, other impairments or contributing factors need to be further assessed. Task performance is not just a function of muscle strength but also of skill and motivation. The potential of the individual is only realized through the collaborative efforts of the patient and the entire multidisciplinary rehabilitation team.

The limitations of this pilot study included a small sample size and limited variability of some MMT and FIM scores making generalization to the whole SCI population difficult. Our sample included two subjects with C7-level lesions, which increased the variance of the MMT and FIM scores. Nevertheless, wrist flexion and elbow extension MMT scores were the lowest of those analyzed. Future studies should include more subjects with lower tetraplegia (C7 and C8) in order to better delineate the contribution of these muscle groups to functional tasks. Also, the current findings are likely biased toward the C5–C6 primary muscles (biceps in particular) and may not be generalized to all levels of tetraplegia. A larger sample would also enable analysis by level of lesion. Patient's physical characteristics such as height and weight were not taken into account, which may have made a difference in the ability to perform some tasks. Future research options may include determining threshold MMT scores for key muscles related to each FIM task and generating and correlating MMT sum scores of related muscle groups for each FIM task in the SCI patient population.

Conclusion

This pilot study demonstrated that specific contributions of key muscle groups to the performance of individual motor FIM tasks in individuals with a lower cervical-level SCI can be identified. This information, when incorporated into rational for treatment planning, may aid in more focused and effective interventions for helping patients achieve their maximum functional capabilities. This model of analysis should be repeated with a larger, more varied sample so that findings could be generalized to the SCI population.

Acknowledgements

We thank Spaulding Rehabilitation Hospital, Boston, MA and Teresa Holmes MS, PT, Rehabilitation Therapies Supervisor at Boston University Medical Center, Boston, MA for their assistance.

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