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# Upper Extremity Function in Persons with Tetraplegia: Relationships Between Strength, Capacity, and the Spinal Cord Independence Measure

Claudia Rudhe, OT, MSc, and Hubertus J. A. van Hedel, PT, PhD

*Objective.* To quantify the relationship between the Spinal Cord Independence Measure III (SCIM III), arm and hand muscle strength, and hand function tests in persons with tetraplegia. *Methods.* A total of 29 individuals with tetraplegia (motor level between cervical 4 and thoracic 1; sensory-motor complete and incomplete) participated. The total score, category scores, and separate items of the SCIM III were compared to the upper extremity motor score (UEMS), an extended manual muscle test (MMT) for 11 upper extremity muscles, and 6 functional capacity tests of the hand. Spearman's correlation coefficients ($r_s$) and regression analyses were performed. *Results.* The SCIM III sum score correlated well with the sum scores of the 3 tests ($r_s \geq .76$). The SCIM III self-care category correlated better with the tests ($r_s \geq .80$) compared to the other categories ($r_s \leq .72$). The SCIM III self-care item "grooming" highly correlated with muscle strength and hand capacity items ($r_s \geq .80$). A combination of hand muscle tests and the key grasping task explained over 90% of the variability in the self-care category scores. *Conclusions.* The SCIM III self-care category reflects upper extremity performance as it contains especially useful and valid items that relate to upper extremity function and capacity tests.

**Keywords:** *Spinal cord injury; Upper extremity; Rehabilitation; Activities of daily living; Motor control*

Several interventions that aim to regenerate lesioned spinal pathways and exploit neuroplastic mechanisms are currently being translated from animal research to human patients with a spinal cord injury (SCI).[1-3] In general, individuals with sensory-motor complete lesions at the thoracic or cervical level are included in such studies. Unlike the difficulties that arise when evaluating fine segmental motor changes (eg, 1 or 2 levels) in muscles that are innervated from the thoracic spinal cord,[4] one would expect that the evaluation of hand and arm muscles, which are innervated from the cervical spinal cord, can easily be performed.[5] Furthermore, the clinical evaluation of hand and arm function is of uttermost importance, as this is assumed to play a key role in activities of daily life (ADL) and independence.[6,7] Indeed, persons with tetraplegia show considerable impairments in personal independence compared to paraplegic persons[8] and 75% of persons with tetraplegia would prefer restoration of their upper limb function to that of any other lost function.[9,10] Therefore, to evaluate the efficacy of rehabilitation and experimental interventions, it is important to have standardized tests that assess upper extremity function validly.

Upper extremity function can be evaluated on several levels according to the International Classification of Functioning, Disability, and Health (ICF).[11] Muscle strength tests, for example, fall under the component "body functions" and assess impairment. Tests that fall under the component "activity and participation" are defined as either capacity qualifiers, when they assess a task in a standardized way, or as performance qualifiers, when they assess a task in a life situation.

Many tests that assess hand and arm capacity exist or are in development. The Van Lieshout test, for example, was developed in 2003 and assesses upper extremity tasks that are associated with daily activities in patients with tetraplegia.[12,13] It is mainly used in the Netherlands. The Capabilities of Upper Extremity test was published in 1998 and is mainly used in the USA, although relatively scarcely applied.[6] The Grasp Release test assesses only lateral and cylindrical grasp, but is internationally more widely applied.[14] The Graded and Redefined Assessment of Strength, Sensation, and Prehension (GRASSP) is currently under development by an international team of specialists. It focuses on muscle, sensory, and grasping function.[15,16] Such specific hand and arm assessments are used by specialized rehabilitation members (occupational and physical therapists or surgeons) or in clinical trials to document specific improvement in hand and arm function.[17,18] Still, none of these tests have reached sufficient international acceptance to become a gold standard in the field of SCI.

In the clinical field, measures for functional independence or ADL assess tasks in a life situation and have become

From the Spinal Cord Injury Center, Balgrist University Hospital, Zurich, Switzerland (CR, HJAvH); The GRASSP Study Group (Graded Redefined Assessment of Strength, Sensibility, and Prehension) (CR); and the EM-SCI Study Group (European Multicenter Study on Human Spinal Cord Injury) (CR, HJAvH). Address correspondence to Hubertus J. A. van Hedel, Spinal Cord Injury Center, Balgrist University Hospital, Forchstrasse 340, CH-8008 Zurich, Switzerland. E-mail: hvanhedel@paralab.balgrist.ch.

standard overall outcome measures. These tests are often used in the validation process for upper extremity assessments.[6,12,13] One of them is the Spinal Cord Independence Measure (SCIM).[19] The SCIM continues to gain widespread international acceptance, and has been revised twice since the original version (the most recent version is the SCIM III).[20] Although the SCIM II has been applied to document changes in hand function,[21] the question as to whether the SCIM reflects upper extremity performance remains unresolved. Therefore, the overall aim of the present study was to explore the relationship between upper extremity muscle strength tests, capacity tests, and the SCIM III in persons with tetraplegia. We hypothesized that: (1) compared to the respiration and sphincter management or mobility categories, the self-care category of the SCIM III correlates better with strength and capacity tests, which would indicate that the SCIM self-care category reflects upper extremity performance; and (2) based on ICF definitions, upper extremity capacity tests can better estimate the SCIM III self-care than muscle strength tests in persons with tetraplegia.

## Methods

### Participants

The data presented in this study were gathered within the larger international multicenter GRASSP study, which currently includes over 70 persons with SCI. The 29 persons that were included in the present study had a traumatic or ischemic SCI and were recruited from 2 German centers (Bayreuth: 8 persons, and Murnau: 10 persons) and 1 Swiss center (Zurich: 11 persons). The time since injury varied between 1 and 15 months (mean ± standard deviation (SD): 4.5 ± 3 months). According to the protocol of the American Spinal Injury Association (ASIA), 12 persons were classified as having a motor-sensory complete lesion (ASIA A), 4 as motor complete but sensory incomplete (ASIA B), and 13 as sensory-motor incomplete (ASIA C and D). The ASIA motor level was defined at cervical 4 (C4) in 7 persons, C5 in 7 persons, C6 in 8 persons, C7 in 5 persons, and thoracic 1 (T1) in 2 persons. The participants' ages ranged from 19 to 81 years (mean ± SD: 50 ± 18 years) and 13 persons were female. We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this research.

### Assessments

All hand and arm specific assessments were performed by trained and experienced occupational therapists. Some parts of the SCIM III were scored by trained and experienced physical therapists and nurses. The SCIM III consists of the following 3 categories: self-care (maximal points = 20); respiration and sphincter management (maximal points = 40); and mobility (maximal points = 40). Each category consists of specific items that are scored according to the relevance for the person with SCI.[20] The time between the assessments of the SCIM III and the hand and arm specific tests was within 5 days. The following assessments were performed:

*UEMS*. According to the American Spinal Injury Association (ASIA) protocol, the key muscle groups of the upper extremity (elbow flexors, wrist extensors, elbow extensors, finger flexors, and finger abductors) were scored between 0 and 5. This sum score could vary between 0 and 50.

*MMT*. This included the testing of the muscle groups that were selected for the GRASSP study and included, in addition to the UEMS muscles, the muscles that perform shoulder abduction, finger extension, thumb flexion, thumb opposition, thumb adduction, and the interossei muscles. Consequently, the sum score could vary between 0 and 110.

*Hand capacity tests*. In a strictly standardized way these tests assessed the following 6 tasks: (1) pouring water from a 0.5 liter bottle into a cup; (2) unscrewing 2 different sized jar tops; (3) moving 9 pegs; (4) inserting a key into a lock and turning it 90°; (5) inserting 4 different sized coins into a coin slot; and (6) screwing 4 different sized nuts onto bolts. The tasks were scored between 0 and 5 according to the grasp used and the completeness of the task within a maximum time. The total score could amount to 30. The 6 items of the capacity test and their scoring are presented in Figure 1. The tests and scoring correspond to those used in the GRASSP study.

### Statistics

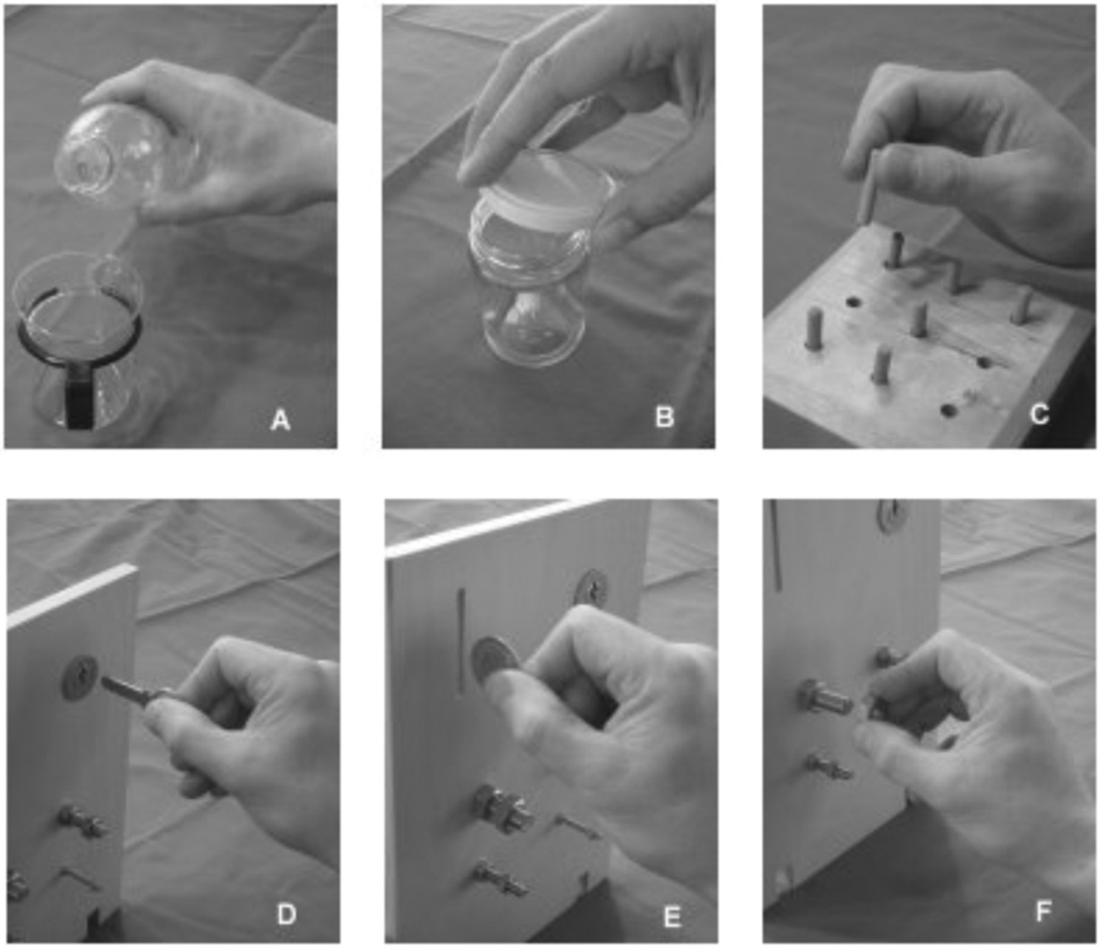
Correlations between the SCIM III total score and the total scores of the muscle and functional tests were performed using nonparametric Spearman's correlation coefficients ($r_s$). Similar statistics were performed when the different items and categories were compared with each other. When single muscle groups (eg, elbow flexors) were correlated with SCIM III scores, the sum score of the left and right muscle groups was included in the analysis. The level of significance was set at .05. Correlations in the range of 0 to.25 were interpreted as none to little, .26 to .50 as fair, .51 to .75 as moderate to good, and .76 to 1.0 as very good to excellent.[22]

To investigate whether muscle strength and functional capacity tests could estimate the SCIM III score, linear regression models were used. First, the sum scores of UEMS, MMT, and the capacity tests were used to estimate the SCIM III score. Then, the optimal combination of specific muscle and hand and arm functional tests was determined using a multiple linear regression analysis. All items that showed significant correlations were included in the model (independent variables) to predict the sum score of those SCIM III categories that showed strong correlations with the sum scores of the muscle and hand function tests. Again, sum scores for left and right muscle groups were used. A backward model was chosen. The probability for entering the model was set at .05 and the probability for removal out of the model was set at .10.

## Results

One person had a stiff right wrist because of arthrosis. Therefore, the strength of the wrist extensors could not be tested

**Figure 1**
**Hand Capacity Tests and Scoring**




**Scoring**
0 – The task can not be conducted at all
1 – The task can not be completed (less than 50% of task) and the expected grasp is not used
2 – The task can not be completed (50% or more of task) and the expected grasp is not used
3 – The task is conducted (completed) using tenodesis or an alternative grasp other than the expected grasp
4 – The task is conducted using the expected grasp with difficulty (lack of smooth movement or difficult slow movement
5 – The task is conducted without difficulties using the expected grasping pattern and unaffected hand function

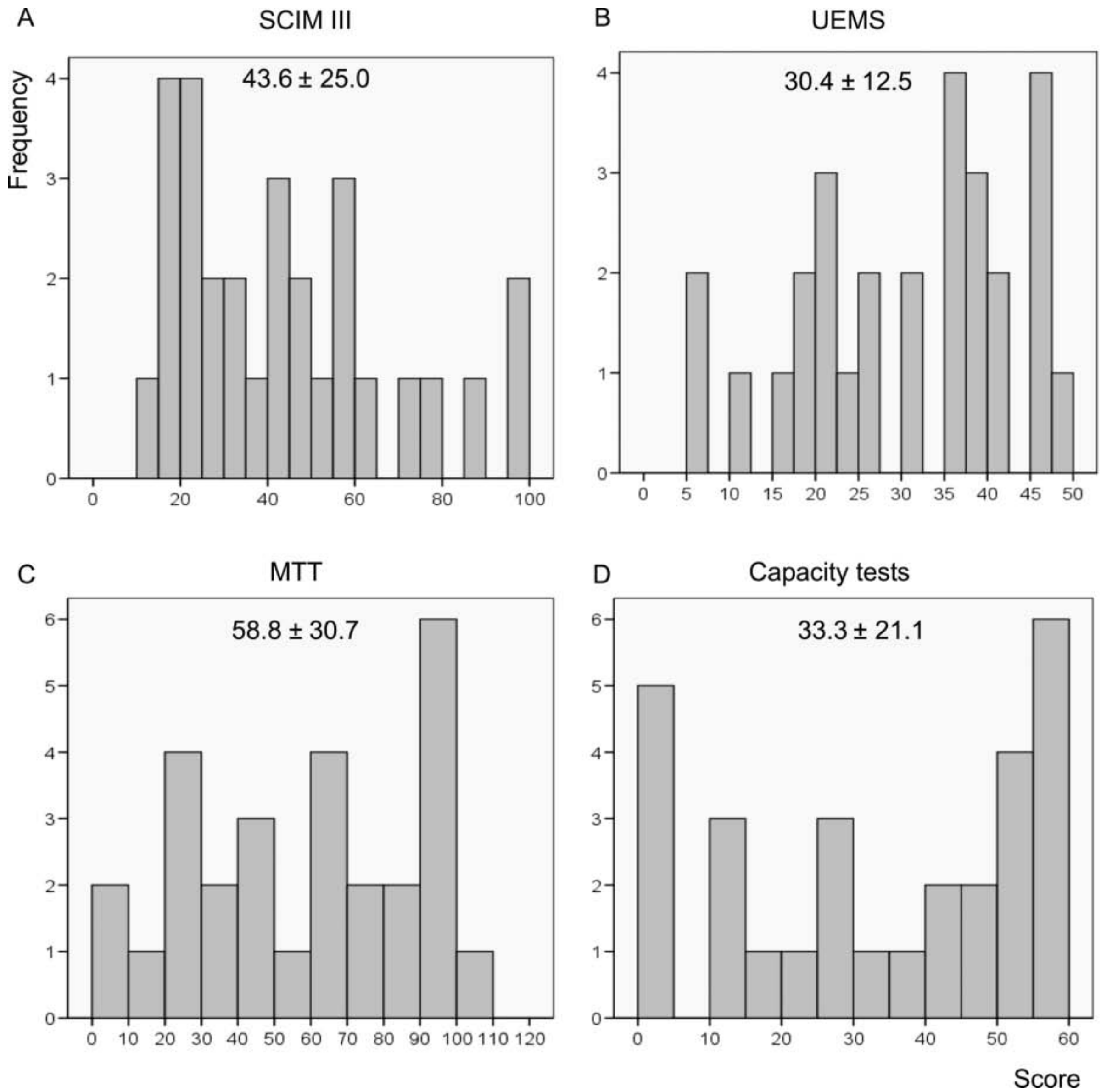
Note: The 6 tasks include: A, pouring water from a 0.51 bottle into a cup; B, unscrewing 2 different sized jar tops; C, moving 9 pegs; D, inserting a key into a lock and turning 90°; E, inserting 4 different sized coins into a coin slot; and F, screwing 4 different sized nuts onto bolts. The scoring was performed according to the GRASSP protocol.

and the data of the person were excluded for those analyses that included wrist extensor strength or the sum of the UEMS and MMT score. Mean values, standard deviations (SD), and the distribution of the scores are presented in Figure 2.

## Total and Category Sum Scores

The total score of the SCIM III correlated very well with the total scores of the UEMS ($r_s$ = .78), the MMT ($r_s$ = .78), and the hand capacity tests ($r_s$ = .76) (for all, $P < .001$; see also Figure 3A-C). The sum score of the self-care category of the SCIM III correlated very well with the UEMS ($r_s$ = .82), the MMT ($r_s$ = .84), and the hand capacity tests ($r_s$ = .80) (for all, $P < .001$; see also Figure 3D-F). Correlations were poorer when the respiration and bladder category sum score was compared with the UEMS ($r_s$ = .63), the MMT ($r_s$ = .68), and the hand capacity tests ($r_s$ = .65) (for all, $P < .001$). Finally, the mobility sum score correlated moderately with the UEMS

**Figure 2**
**Distributions of the SCIM III, UEMS, MMT, and Hand Capacity Sum Scores**




Note: Histogram showing the distribution of the sum scores of the (A) Spinal Cord Independence Measure III (SCIM III), (B) upper extremity motor score (UEMS), (C) manual muscle test (MMT), and (D) the hand capacity tests. The mean ± standard deviation values are also presented.

($r_s$ = 0.65), the MMT ($r_s$ = .71), and the hand capacity tests ($r_s$ = .72) (for all, $P < .001$). We therefore focused further on the relationship between items in the self-care category and the upper extremity strength and hand capacity tests.

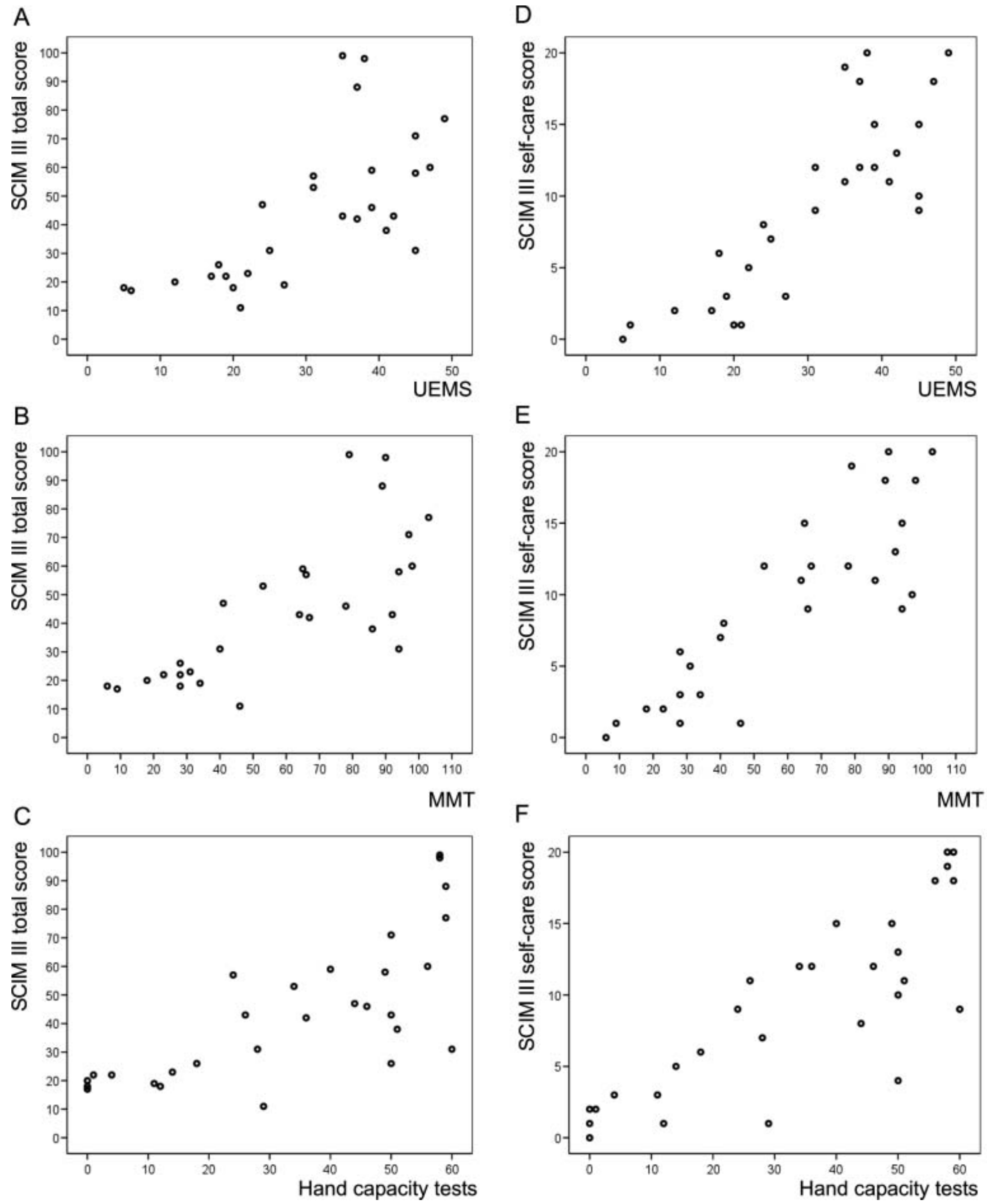
## Self-Care Item Scores Versus Strength and Capacity Total Scores

The relationships between the SCIM III self-care items and the sum scores of the strength and hand capacity tests are shown in Table 1. The item of "grooming" showed the best correlation with the sum scores of the muscle strength and hand capacity tests, followed by the item "bathing upper body."

## Self-Care Item Scores Versus the Muscle Strength Item Scores

The relationships between the SCIM III self-care items and the sum scores of the left and the right muscles are presented in Table 2. The finger extension and finger flexion show the highest correlation with the self-care items followed by the thumb flexor, finger abduction, and elbow extension. Fine finger function

**Figure 3**
**SCIM III Total and Self-Care Scores Versus UEMS, MMT, and Hand Capacity**




Note: Scatter-plots showing the relationship between the Spinal Cord Independence Measure III (SCIM III) total score and the (A) upper extremity motor score (UEMS), (B) manual muscle testing (MMT) sum score, and (C) sum score of the hand capacity tests. Similarly, the relationships between the SCIM III self-care score and the (D) UEMS, (E) MMT, and (F) hand capacity tests scores are also presented.

showed a better correlation with the SCIM III self-care items than the gross motor function of the arm and shoulder.

## Self-Care Item Scores Versus the Hand Capacity Test Scores

In general, the relationships between the SCIM III self-care item scores and the hand capacity test scores varied between good and very good (see Table 3 for details). The moving pegs task and the key grasping task showed the best correlation with the self-care items, followed by the coin insertion task (Table 3).

## Prediction of Self-Care Independence

The previous analyses showed that especially the self-care category revealed very good correlations with the sum scores and item scores of the UEMS, MMT, and the hand capacity tests. To investigate how well the muscle strength and hand capacity tests could estimate the SCIM III self-care score,

**Table 1**
**Self-Care Item Scores Versus Strength and Capacity Total Scores**

| SCIM III Self-Care Items | UEMS | MMT | Hand Capacity Tests |
|---|---|---|---|
| Feeding | 0.73 | 0.75[a] | 0.67 |
| Bathing upper body | 0.80[a] | 0.77[a] | 0.77[a] |
| Bathing lower body | 0.72 | 0.76[a] | 0.71 |
| Dressing upper body | 0.73 | 0.76[a] | 0.80[a] |
| Dressing lower body | 0.64 | 0.70 | 0.60 |
| Grooming | 0.88[a] | 0.89[a] | 0.80[a] |

Abbreviations: SCIM III, Spinal Cord Independence Measure III; UEMS, upper extremity muscle score; MMT, manual muscle testing.
Note: The relationships were quantified using nonparametric Spearman's correlation coefficients. All correlations were significant at the $P < .001$ level.
[a]Correlations ≥ 0.75.

several analyses were performed. First, the SCIM III self-care score was estimated by the following UEMS, MMT, and hand capacity sum scores: (1) for UEMS, SCIM III self-care score = –3.56 + 0.43 × UEMS ($R^2_{adjusted} = .69$); (2) for MMT, SCIM III self-care score = –1.15 + 0.18 × MMT ($R^2_{adjusted} = .73$); and (3) for hand capacity sum scores, SCIM III self-care score = –0.91 + 0.25 × capacity tests score ($R^2_{adjusted} = .68$). These equations indicate, for example, that if the UEMS of a person with tetraplegia is 38, the estimated SCIM III self-care score would be 13 (ie, –3.56 + 0.43 × 38). The variability in UEMS sum score could explain 69% of the variability in the SCIM III self-care score. Second, all 11 muscles used in the MMT and all 6 items of the hand capacity test were included as independent variables in a multiple regression analysis to estimate the SCIM III self-care score. The regression equation was as follows: SCIM III self-care score = 2.11 + 3.49 × finger flexors – 0.58 × finger

**Table 2**
**Self-Care Item Scores Versus Strength Item Scores**

| | SCIM III Self-Care Items | | | | | | |
|---|---|---|---|---|---|---|---|
| MMT Items | Feeding | Bathing Upper Body | Bathing Lower Body | Dressing Upper Body | Dressing Lower Body | Grooming | Sum Self-Care |
| Shoulder abduction | 0.55 | 0.61 | 0.41[b] | 0.66 | 0.34[b] | 0.47[b] | 0.61 |
| Elbow extension | 0.62 | 0.75[a] | 0.63 | 0.66 | 0.62 | 0.78[a] | 0.70 |
| Elbow flexion | 0.27[b] | 0.40[b] | 0.08[b] | 0.39[b] | 0.09[b] | 0.28[b] | 0.36[b] |
| Wrist extension | 0.40[b] | 0.56 | 0.27[b] | 0.43[b] | 0.24[b] | 0.47[b] | 0.42[b] |
| Finger extension | 0.74 | 0.66 | 0.74 | 0.74 | 0.67 | 0.82[a] | 0.82[a] |
| Finger flexion | 0.69 | 0.73 | 0.79[a] | 0.76[a] | 0.72 | 0.84[a] | 0.78[a] |
| Thumb flexion | 0.63 | 0.66 | 0.72 | 0.72 | 0.68 | 0.82[a] | 0.74 |
| Finger abduction | 0.67 | 0.70 | 0.70 | 0.66 | 0.65 | 0.83[a] | 0.71 |
| Interosseus muscle I | 0.64 | 0.67 | 0.68 | 0.66 | 0.65 | 0.77[a] | 0.67 |
| Thumb adduction | 0.58 | 0.65 | 0.63 | 0.63 | 0.56 | 0.74 | 0.63 |
| Thumb opposition | 0.55 | 0.61 | 0.70 | 0.67 | 0.61 | 0.72 | 0.66 |

Abbreviations: SCIM III, Spinal Cord Independence Measure III; MMT, manual muscle testing.
Note: Nonparametric Spearman's correlation coefficients calculated between the self-care items and the sum score of the left and right muscle of the MMT, N = 29 (except for wrist extension, N = 28). Please note that by N = 28, correlations ≥ 0.377 are statistically significant at the $P < .05$ level, and ≥ 0.496 at the $P < .01$ level.
[a]Correlations ≥ 0.75.
[b]Correlations ≤ 0.50.

**Table 3**
**Self-Care Item Scores Versus the Hand Capacity Test Scores**

| | SCIM III Self-Care Items | | | | | | |
|---|---|---|---|---|---|---|---|
| Hand Capacity Test Items | Feeding | Bathing Upper Body | Bathing Lower Body | Dressing Upper Body | Dressing Lower Body | Grooming | Sum Self-Care |
| Bottle | 0.49[b] | 0.69 | 0.68 | 0.76[a] | 0.59 | 0.69 | 0.70 |
| Jars | 0.50[b] | 0.69 | 0.65 | 0.69 | 0.50[b] | 0.63 | 0.65 |
| Pegs | 0.69 | 0.77[a] | 0.73 | 0.81[a] | 0.59 | 0.79[a] | 0.81[a] |
| Key | 0.64 | 0.77[a] | 0.71 | 0.83[a] | 0.67 | 0.77[a] | 0.81[a] |
| Coins | 0.65 | 0.75[a] | 0.76[a] | 0.82[a] | 0.65 | 0.79[a] | 0.77[a] |
| Nuts | 0.64 | 0.69 | 0.67 | 0.74 | 0.55 | 0.75[a] | 0.76[a] |
| Sum score | 0.67 | 0.77[a] | 0.71 | 0.80[a] | 0.60 | 0.80[a] | 0.79[a] |

Abbreviations: SCIM III, Spinal Cord Independence Measure III.
Note: Nonparametric Spearman's correlations calculated between the SCIM self-care items and the hand capacity test items, N = 29. All correlations were significant ($P \leq .01$).
[a]Correlations ≥ 0.75.
[b]Correlations ≤ 0.50.

**Table 4**
**Multiple Linear Regression Model Explaining the Self-Care Sum Score**

| Item | Regression Coefficient | Standard Error | Significance (*P* Value) | 95% CI |
|---|---|---|---|---|
| Constant | 2.11 | 0.55 | .001 | 0.97 to 3.25 |
| Finger flexion | 3.49 | 0.51 | < .001 | 2.43 to 4.54 |
| Finger extension | −0.58 | 0.28 | .047 | −1.16 to −0.01 |
| Thumb flexion | 1.64 | 0.43 | .001 | 0.75 to 2.52 |
| Finger abduction | −2.90 | 0.42 | < .001 | −3.77 to −2.03 |
| Thumb opposition | −1.63 | 0.36 | < .001 | −2.38 to −0.87 |
| Key | 1.05 | 0.16 | < .001 | 0.71 to 1.39 |

Abbreviations: CI, confidence interval.
Note: Most assumptions required for multiple regression analyses were met, with the exception of collinearity between the finger flexor, thumb flexor, finger abductor, and thumb opposition muscles (variance inflation factor > 10). We repeated the analysis 4 times, each time excluding 1 of these independent variables. For each model, the explained variance was reduced by 10% to 20% or the deleted variable was replaced by another variable. Therefore, as the standard errors of the regression coefficients were small, we assume that collinearity was not an issue.

extensors + 1.64 × thumb flexor − 2.90 × finger abductors − 1.63 × thumb opposition + 1.05 × key grasping task. The model explained over 90% of the variance in SCIM III self-care ($R^2_{adjusted}$ = .93). Detailed information about the regression equation can be found in Table 4.

## Discussion

Although the SCIM III has been used to evaluate changes in hand function,[21] exact relationships between SCIM III and hand function and capacity are unclear. Therefore, the aim of the present study was to investigate the relationship between the SCIM III and several upper extremity assessments that quantified muscle strength and hand capacity. The main findings were the following:

1. The total SCIM III score correlated very well with the sum scores of the UEMS, MMT, and hand capacity tests.

2. As hypothesized, the sum score of the self-care category of the SCIM III correlated best with the upper extremity assessments, compared to respiration and sphincter management or mobility categories of the SCIM III. Therefore, we suggest that the SCIM III self-care score reflects upper extremity performance.

3. Many individual items of the self-care category showed excellent correlations with the upper extremity tests.

4. The sum scores of the UEMS, MMT, and capacity tests could estimate self-care independence similarly. In contrast to our hypothesis, the upper extremity capacity tests were not superior to the muscle strength tests in estimating the SCIM III self-care score.

5. A combination of 5 muscle tests and 1 hand capacity test could estimate self-care independence excellently.

### SCIM III and Upper Extremity Function

Apparently, the SCIM III self-care category, and several of its items, reflect upper extremity performance. Indeed, the SCIM III item “grooming” appears to be especially well correlated with strength and capacity in the hand and arm, followed by bathing of the upper body. From a clinical point of view, it was expected that feeding would relate better to upper extremity strength and capacity compared to, for example, bathing or dressing the upper body. While these latter activities might be more related to the stability of the trunk, feeding requires many fine hand and finger movements (eg, for opening containers or handling cutlery). However, this expectation was not confirmed in the current study.

### Estimating Self-Care Independence Using Upper Extremity Tests

We assume that by restoring upper extremity function, self-care independence should improve. Indeed, the UEMS, MMT, and hand capacity sum scores were able to estimate the SCIM III self-care score. Still, a combination of several separate muscle and capacity test items was superior in estimating self-care independence, indicating that information is lost when using sum scores. Furthermore, as only 2 of these muscle groups are included in the ASIA protocol (ie, finger flexors and abductors), we suggest that to accurately predict self-care independence the ASIA protocol needs to be extended by the inclusion of additional muscle or hand capacity tests.

Distal muscle groups in particular were able to estimate self-care independence especially well. At first glance, the importance of the distal muscle groups appears unexpected, as in daily life activities, the use of proximal muscles can make a large difference (eg, when transferring from the toilet to the wheelchair). The lack of upper limb strength tasks among the self-care items, however, may have decreased the relevance of large muscles for overall functioning. In addition, in individuals with a complete SCI, functional distal muscles strongly indicate the presence of functional proximal muscles, although this is not necessarily the case in participants with an incomplete SCI.

### Upper Extremity Muscle Strength and Dexterity

According to ICF definitions, we hypothesized that upper extremity capacity tests could predict self-care independence better than muscle strength tests. We did not find this, however, which could be explained by the excellent correlations between the UEMS, MMT, and capacity tests ($r_s$ > .86). Furthermore, only 1 hand capacity test (ie, the key grasping task) remained in the multiple regression equation. This might allow the provocative statement that muscle strength rather than dexterity is a key factor for self-care independence after a SCI. Indeed, some aspects of dexterity remained intact in participants with an incomplete SCI,[23] when strength was severely affected. Such findings were also observed in patients with stroke.[24,25]

## Methodological Considerations

This study has several limitations. First, there is no gold standard to assess hand and arm function in persons with SCI. This study merely assesses relationships between measures assessing upper extremity strength, capacity, and self-care independence. We suggest that the good correlations between upper extremity strength and capacity tests and the SCIM III self-care score indicate concurrent validity of the self-care category to assess upper extremity performance.

Second, in the present sample of persons with tetraplegia, the motor level of lesion varied between the C4 and T1. We suggest that this sample provides a reasonably good representation of the group of individuals with significant loss of hand function. From clinical experience, persons with a lesion of C5 and below usually have enough shoulder function to position their arm and use it in a functional context. Only 2 participants had a lesion below C7. These individuals usually experience a minimal loss of hand function and are able to demonstrate a similar performance in ADL activities as persons with a high paraplegic lesion. We are therefore confident that the present findings can be generalized to the population of persons with tetraplegia.

Third, our results indicate that the SCIM III, and especially the self-care category, are practical and valid measures for the assessment of hand function. However, further aspects such as reliability and responsiveness are important in determining whether such assessments can be used in evaluating rehabilitation programs or experimental interventions. Previous studies showed that the reliability of the SCIM II was good, as the agreement between 2 raters on the self-care items was found to vary between 80% (bathing lower body) and 99% (feeding)[26] and the correlations between 2 raters were high for the self-care sum score ($r_s = .96$) and the SCIM II total score ($r_s = .99$). Furthermore, the reliability of the SCIM III was also found to be good.[27]

The responsiveness of the SCIM III is better than that of the Functional Independence Measure.[27] Furthermore, in motor complete tetraplegic participants, both the self-care sum score and the SCIM II total score improved significantly between 1 and 3 months and between 3 and 6 months, whereas no differences were observed between 6 and 12 months.[8] In addition, several single items of the SCIM II improved between 1 and 3 months and between 3 and 6 months.[8] These results indicate that the SCIM total score, the self-care category, and several items within this category are sensitive to change in motor complete tetraplegic participants. However, as we are unaware of the size of such changes in, for example, the upper extremity capacity tests included in this study, the question concerning responsiveness remains unsolved and needs further evaluation in longitudinal studies.

## Conclusions

In conclusion, the self-care category of the SCIM III and several of its items correlate well with upper extremity strength and capacity tests in persons with tetraplegia. Therefore, we suggest that the SCIM III self-care category can assess upper extremity performance. The upper extremity capacity tests we examined were not superior to the muscle strength tests in estimating self-care independence. When muscle strength tests are used to estimate self-care independence, we recommend extending the ASIA protocol by testing additional muscles or functional hand and arm capacity tests. The use of the SCIM III concerning hand function for studies requires further evaluation, as the responsiveness of the SCIM III categories and items compared to other measures assessing upper extremity function remains unresolved.

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