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Original Article

Five additional mobility and locomotor items to improve responsiveness of the FIM in wheelchair-dependent individuals with spinal cord injury

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Study design: Repeated-measures design.
Objectives: To assess the validity and responsiveness of five additional mobility and locomotor (5-AML) items when used in conjunction with the Functional Independence Measure (FIM) for assessing the mobility and locomotor function of individuals with spinal cord injury (SCI).
Setting: Specialised acute spinal and rehabilitation units in Sydney, Australia.
Methods: A previously published scale comprising five key mobility and locomotor skills was further refined. The five items included a bed mobility and vertical (floor-to-chair) transfer item and three wheelchair propulsion items (pushing 200 m over flat ground, pushing up a ramp and negotiating a kerb). A total of 43 eligible patients with SCI (ASIA A–C impairment) admitted consecutively to two acute SCI units in Sydney between 1999 and 2002 were recruited, with four being lost to follow-up. Locomotor and mobility outcomes were measured at regular intervals for up to 6 months with the FIM and the 5-AML. Construct validity of the 5-AML was assessed by testing ability of items to discriminate between different impairment groups (tetraplegia and paraplegia). Item responsiveness was assessed by analysing ability to detect changes in mobility and locomotor function over time. Factor analysis techniques were used to test the hypothesis that the 5-AML, when used in conjunction with the FIM, provides a more sensitive measure of mobility and locomotor function than the FIM alone.
Results: The 5-AML items were shown to be valid and responsive, measuring aspects of 'real world' mobility and locomotor function not reflected by the FIM. The bed mobility item was highly responsive to change over time for the tetraplegic group, but quickly reached a ceiling in the paraplegic group. The vertical (floor-to-chair) transfer item showed greater responsiveness over time and less ceiling effect for the paraplegic group than any of the FIM locomotor or mobility items. The three wheelchair propulsion items better discriminated between people with tetraplegia and paraplegia, and were more sensitive to changes in locomotor ability over the 6-month period than FIM locomotor items. Results of a preliminary factor analysis indicated that the 5-AML items measure different aspects of mobility and locomotor function than the FIM.
Conclusion: The 5-AML items, when used in conjunction with the FIM, provides better delineation of function between people with tetraplegia and paraplegia and provides a more responsive measure of change in function over time than the FIM alone.
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Keywords: spinal cord injury; rehabilitation; outcome measurement; disability; mobility

Introduction

Measurements of functional outcomes are an integral part of any goal orientated, interdisciplinary rehabilitation programme and are important for quantifying the success of rehabilitation programme. The Functional Independence Measure (FIM) has gained widespread acceptance as a universal tool for functional assessment in rehabilitation. The FIM was designed to measure severity of disability and to determine 'burden of care' in

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core life activities across a range of impairments.[1] It contains 18 items rated on a seven-point scale that reflect the amount of assistance a person requires in the areas of self-care, sphincter control, mobility, locomotion, communication and social cognition. The FIM has attained general acceptance largely because of its practical nature, reliability and ability to measure functional aspects of individuals' overall independence.[2] However, the validity of the FIM in the spinal cord injury (SCI) population has not been proven[3] and it has some well-recognised limitations.[4]

The FIM was originally intended to measure burden of care, rather than level of functional independence, and was not specifically designed for people with SCI. It is therefore not surprising that there are some inherent problems with the FIM when used to demonstrate the success of rehabilitation programmes in the spinal cord injured population. In particular, the mobility and locomotor items of the FIM appear to lack sensitivity and the ability to distinguish important functional differences between individuals with different SCI impairments. This is reflected in the results of various studies that have failed to detect changes in function of patients over time and failed to detect differences in function of patients of various ages and neurological lesions. For instance, an early study by Menter *et al*[5] found little variation in FIM scores between individuals with high level (T3–4) and low level (T11) paraplegia or between younger (<30 years) and older (>45 years) individuals. Dodds *et al*[3] showed that although the FIM could discriminate between complete paraplegic and tetraplegic groups, the FIM was unable to demonstrate distinct differences along the continuum from high tetraplegia to low paraplegia, particularly when incomplete lesions were included. Similarly, Ota *et al*[6] in their study of 100 patients with SCI found no differences in the FIM scores of persons with C8 tetraplegia, T1–5 paraplegia and T5–12 paraplegia, and Marino *et al*[7] showed no improvement over a 3-month period following injury.

More recently, research by our own group,[4] measuring functional outcome at discharge in 112 individuals with SCI, revealed that the FIM locomotor items were largely insensitive with marked ceiling and floor effects. In addition, the FIM locomotor items failed to delineate important functional differences between patients with different neurological lesions.

A number of alternative assessment tools have been proposed to assess functional independence more broadly. Particular emphasis has been placed on relating these assessment tools to individuals' level of participation and activity (as specifically described in the International Classification of Functioning, Disability and Health – WHO, 2001).[8] For instance, both the Spinal Cord Independence Measure (SCIM)[9] and the Quadriplegic Index of Function[7] have been proposed as alternatives to the FIM. Several other assessment tools, specifically designed to assess the mobility and/or locomotion function of wheelchair-dependent individuals, have also been designed (reviewed by Kilkens *et al*[11]). These include the Wheelchair Skills Test,[10] Wheelchair Circuit[11] and the Harvey Mobility Assessment Tool.[12] While all the described assessment tools have merit, none have yet gained as widespread acceptance as the FIM nor been associated with such a well-organised, comprehensive education and accreditation programme. We therefore believed that time and effort may be better directed at improving the sensitivity of the FIM to detect important functional changes by adding a few simple FIM-like items, rather than advocating the use of different assessment tools.

Our aim therefore was to assess the responsiveness and discriminant validity of five additional mobility and locomotor (5-AML) items that could be used in conjunction with the FIM to enhance its sensitivity and better reflect relevant functional improvements with rehabilitation. We sought to determine the ability of the 5-AML to distinguish between individuals with varying neurological deficits (discriminant validity) and the ability of the 5-AML to detect changes in function over time (responsiveness). The 5-AML items were adapted from a six-item assessment tool of our own[12] that was originally designed for wheelchair-dependent individuals with paraplegia. The original tool was devised by a group of Sydney physiotherapists experienced in the management of people with SCI. It was shown to have face validity with good interobserver reliability (weighted kappa 0.82–0.98[12]). The original tool has since been slightly modified to ensure that the items were appropriate for persons with tetraplegia and the scoring consistent with the FIM. While the initial assessment tool included a bed transfer item, this was removed as it measured the same domain as the existing three transfer items of the FIM. Hence, the five additional items that were trialed assessed the ability of wheelchair-dependent individuals with paraplegia and tetraplegia to move about on a bed, transfer from floor to wheelchair and push a manual wheelchair over level ground, ramps, and kerbs (see Appendix). It was hoped that by including both simple and complex tasks the scale would be able to better delineate important functional differences between groups with different levels of neurological impairment and would also help to eliminate the floor and ceiling effect of the FIM.

Methods

Subjects

Patients admitted to two acute spinal injury units in Sydney, Australia (The Royal North Shore Hospital and the Prince of Wales Hospital) between 1999 and 2002 were identified if they presented with a sudden onset of paraplegia or tetraplegia following trauma, surgery or a medical condition. The project was approved by the relevant hospital Human Research Ethics Committees and all participants signed an informed consent sheet. Inclusion criteria were persons aged between 18 and 65 years with a persisting neurological deficit following acute SCI. Patients likely to be transferred overseas within 6 months, patients with complete motor lesions at or above C4 and patients with ASIA Grade D impairments or motor function likely to enable the individual to walk, as well as those with multiple fractures were excluded from the study. One patient was excluded because of a psychiatric disorder. In all, 43 patients were included in the study.

Patients were tested within 72 h of mobilising in a wheelchair for the first time since injury, then 1 month, 2 months, 3 months and 6 months later (often after the person had been discharged from hospital). All but two subjects were assessed at one of the two acute hospitals or their affiliated rehabilitation centres. The remaining two subjects were unable to return to hospital for their 6 month assessment and consequently were self-assessed by telephone. In addition, data were missing for two subjects (both with paraplegia) at the 6-month follow-up. For these two subjects, data at 3 months were used to replace the data missing at 6 months. Data from another four subjects (all with paraplegia) were missing for two or more follow-up periods. These subjects were considered lost to follow-up and excluded from analyses. In this way, data from 39 of the original 43 subjects were included in the analysis.

Assessment procedure

At each assessment, subjects were scored using the ASIA sensory and motor examination,[2] the locomotor and mobility subitems of the FIM[13] and the 5-AML items. The ASIA examination is an accepted method of quantifying the neurological status of people with spinal cord injury and the FIM is a widely used measure of activity limitation for people with disabilities. Accredited staff of the two acute and rehabilitation units performed all FIM assessments. A research physiotherapist unaware of subjects' FIM scores and experienced in SCI rehabilitation assessed subjects with the 5-AML items. The use of independent assessors to collect different aspects of the data reduced intraobserver bias.

Details of the 5-AML items

Tasks from an original mobility scale developed by Harvey *et al*[12] were further refined and standardised. In particular, items were modified to ensure suitability for individuals with tetraplegia (see Appendix) and scoring was adjusted to a seven-point scale. The horizontal transfer item of the original scale was omitted because of its similarity with the FIM bed-transfer item.

The 5-AML items included two mobility and three locomotor items. One mobility item assessed patients' abilities to get from a supine position in the middle of a gymnasium plinth (width approximately 108 cm) to a sitting position on the edge of the plinth in preparation for transfer. Patients were assessed on their ability to perform this motor task without an electric bed. The other mobility item assessed patients' abilities to get from the floor back into their wheelchair. The three locomotor items assessed patients' abilities to propel a manual wheelchair over flat ground, ramps and kerbs. Subjects were assessed in a manual rather than motorised wheelchair to validate the 5-AML locomotion items. The decision to assess subjects in manual, rather than motorised wheelchair, was based on the belief that the ability to mobilise in a manual wheelchair reflects an important aspect of independence. People with SCI often rely on a manual wheelchair when out in the community, especially if they depend for transport on vehicles unable to accommodate a motorised wheelchair. There is limited value in assessing individuals' abilities to mobilise in a motorised wheelchair because mobility of people confined to electric wheelchairs is highly predictable and primarily reflects access to appropriate equipment.

Criteria for scoring the bed mobility and vertical transfer items were based on ability to complete the four key components of each task independently and within a reasonable amount of time (<3 min). Scoring criteria for the three additional locomotion items (ie pushing wheelchair on the flat, up and down a ramp, and negotiating kerbs) were based on a combination of factors, including standards for functional independence in the community (eg wheeling at ~ 1.1 m/s to safely cross pedestrian crossing, ability to push up and down 1:14 gradient ramp, and negotiate 15 cm high kerb), practical distances and/or time limits, as well as a desire to discriminate effectively between different levels of impairment and physical capacity. With wheelchair pushing over level ground, for example, a decision was taken to set the highest score of '7' (ie 'complete independence') for pushing wheelchair a distance of 200 m at a fast propulsion speed (ie $> \sim 2.2$ m/s) to avoid ceiling effects and acknowledge the fact that increased levels of physical capacity have been associated with reduced physical strain during activities of daily living (Janssen *et al*[14]) and a lower risk of medical complications, such as cardiovascular disease and development of pressure sores.

Statistical analysis

Subjects were classified by impairment into two groups, namely people with tetraplegia (C5–C8) and people with paraplegia (T1 and below). All subjects' classifications remained constant over the course of the study. That is, their initial neurological classification did not change over the 6-month follow-up period. Median and interquartile ranges were derived for all item variables and represented in figure form as standard boxplots. Since data were ordinal, nonparametric statistics were employed. Construct validity was assessed by testing the ability of the 5-AML items to discriminate between neurological impairments (tetraplegia and paraplegia) using Mann–Whitney *U*-test at each time point. Item responsiveness over time was assessed by testing change over time (namely at 72 h, 1 month, 2 months, 3 months and 6 months after initial mobilisation) using the Friedman Test for repeated-measures. SPSS for Windows Version 10[15] was used for all statistical analyses.

Exploratory factor analysis, as recommended by Streiner[16,17] and Gorsuch,[18] was used to determine whether using the 5-AML items in combination with the FIM provided additional unique (or redundant) information. Factor analysis is a statistical procedure used to detect relationships between variables in a way that allows data to be reduced and intercorrelated variables to be grouped (or classified) into a limited number of common factors that explain the variability. Data at 1 month were used for this analysis because change in mobility and locomotor function was likely to be most pronounced at this time. Data from other time periods were then used to test the scale's responsiveness over time.

Prior to conducting the factor analysis, items that showed restriction in range were rejected. The 'maximum likelihood' approach was then used to estimate an initial 'best' representation of the relationship between variables, assuming that the observed variables and unobservable common factors have underlying multivariate normal distributions.[19] The variance maximising (varimax) method[20] was employed to reduce factorial complexity and assist easier interpretation, whereby the axes of initial factor scatterplot are rotated to distribute variance across factors more evenly and produce a pattern of loadings on each factor that is as diverse as possible. Eigenvalues of '1.0' or more (accounting for equal or greater variance than is generated by one value) and visual inspection of the scree plot were used as criteria for retention of factors.[21] The scree procedure (which plots eigenvalues for each item in descending order) provides a solution with the minimum number of factors accounting for the maximum amount of variance, whereby a clear break or change in the slope of plot curve is identified. Only items with a factor loading coefficient $\geqslant 0.5$ were included in each factor. Items were given equal weighting in the scoring procedure regardless of the size of the loading coefficient, as recommended by Gorsuch.[18]

Cronbach's alpha coefficient[22] was calculated to establish the internal consistency of the items within each subscale and between each of the subscales. An alpha value of 0.6–0.7 was considered optimal, while a coefficient >0.9 was considered indicative of item redundancy.[23] The construct validity of each subscale was examined by calculating the subscale scores and using nonparametric statistical tests[24] to analyse differences between groups (tetraplegic and paraplegic) and within group differences over time.

Results

Table 1 provides information about the neurological status of subjects according to ASIA standards. All ($n=39$) but seven subjects were male. The median (interquartile range) age of subjects was 28 years (22–35 years). A total of 11 subjects were classified into the tetraplegic group and the remaining 28 into the paraplegic group.

Table 1 Characteristics of subjects (median and interquartile ranges) including age, sex and ASIA motor and sensory scores

	Tetraplegic group (n = *11*)	*Paraplegic group* (n = *28*)
Male subjects	7	25
Female subjects	4	3
Age	27 (19–32)	29 (23–35)
ASIA motor		
Initial	17 (13–23)	50 (50–50)
6 months	24 (18–31)	50 (50–56)
ASIA sensory		
Initial	44 (31–84)	137 (100–146)
6 months	68 (42–122)	130 (104–149)

ASIA scores relate to first mobilisation in the wheelchair (initial) and 6 months later

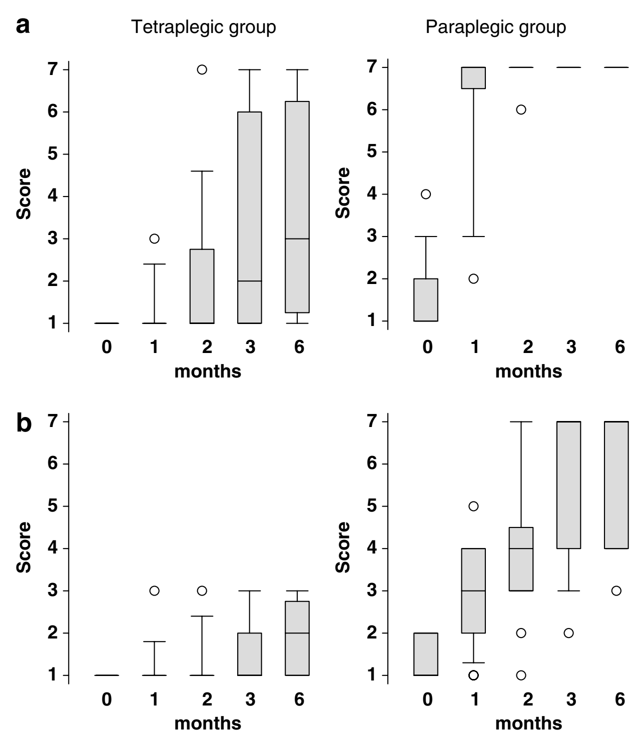

Figure 1 Boxplots for mobility items of the 5-AML items. (**a**) Bed mobility item, (**b**) vertical transfer item

5-AML items

The results of the 5-AML items are presented in Figures 1 and 2. The *bed mobility* item (Figure 1a) demonstrates high responsiveness to change over time in the tetraplegic group, but quickly reaches a ceiling in the paraplegic group. The *floor-to-chair transfer* item (Figure 1b) discriminates effectively between the impairment groups with good responsiveness shown in the paraplegic group. All three locomotor items (Figure 2) differentiate between the tetraplegic and paraplegic groups. They show early responsiveness in the paraplegic group, although a later ceiling effect is reached for

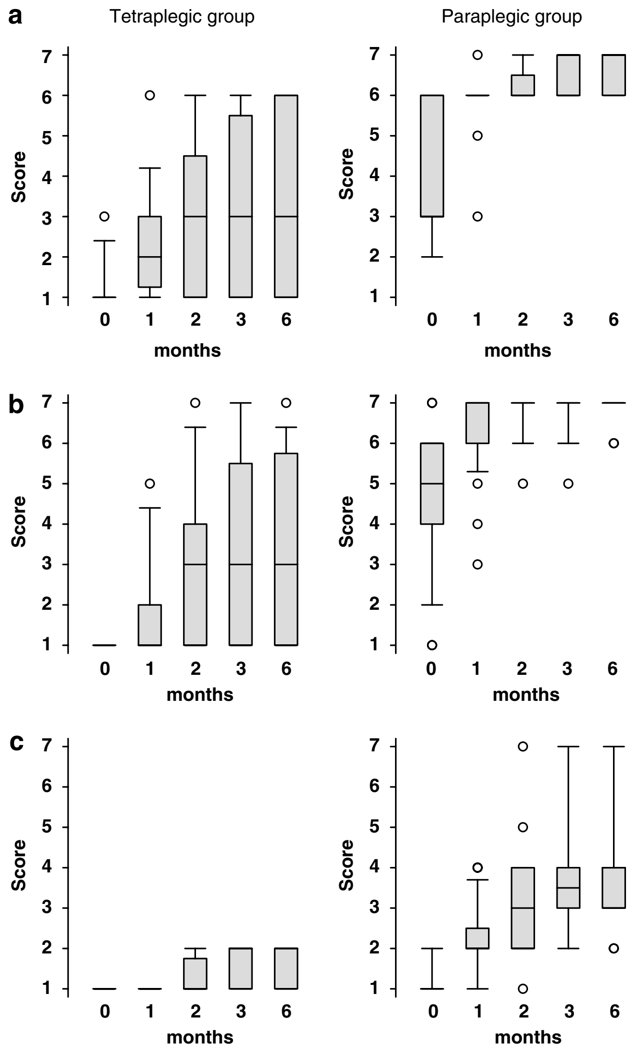

Figure 2 Boxplots for locomotor items of the 5-AML items. (**a**) Push on the flat item, (**b**) push on ramp item, (**c**) push on kerb item

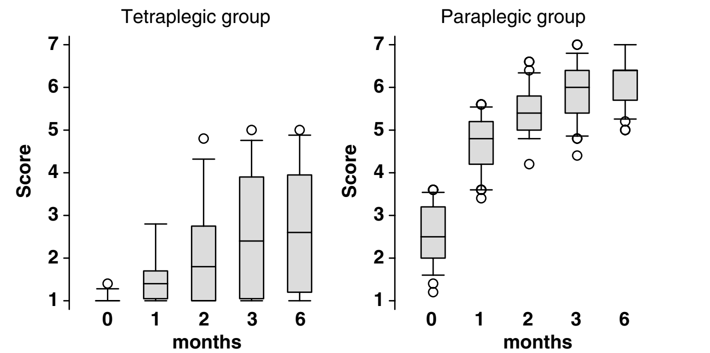

Figure 3 Boxplots for averaged score of the 5-AML items

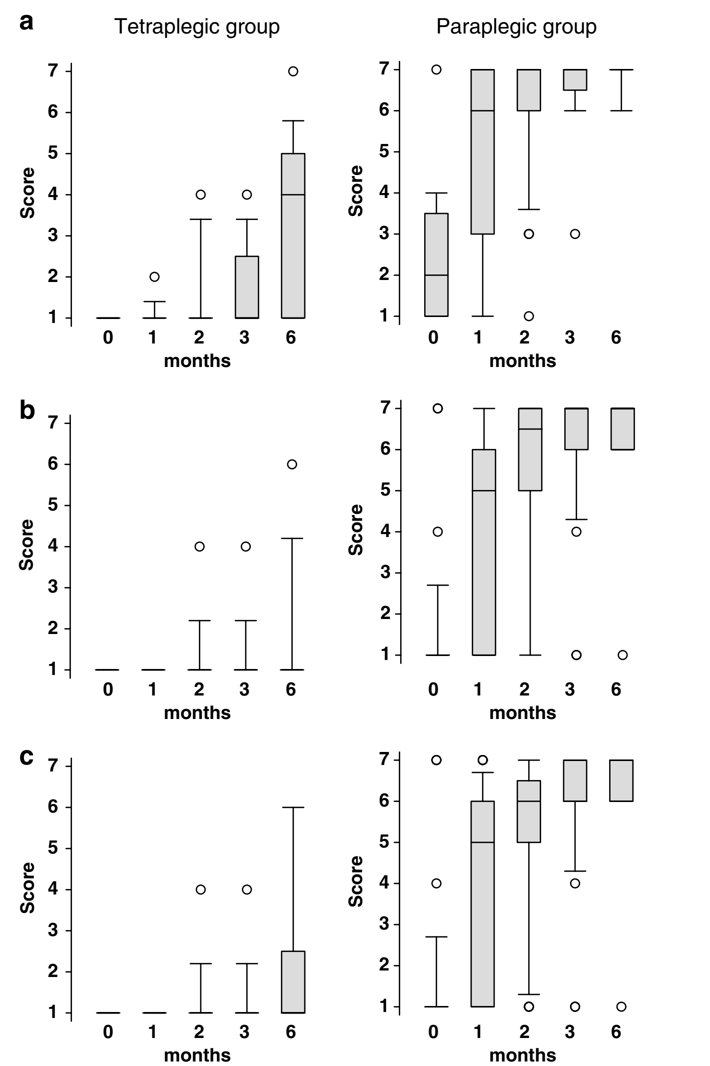

Figure 4 Boxplots for FIM mobility items. (**a**) Bed transfer item, (**b**) toilet transfer item, (**c**) bath transfer item

the *flat push* (Figure 2a) and *ramp* (Figure 2b) items for this group. The *flat push* and *ramp* items also show early responsiveness for the tetraplegic group. In contrast, the *kerb* item (Figure 2c) shows poor responsiveness for the tetraplegic group with a clear floor effect. The *kerb* item does, however, demonstrate good responsiveness to change over time for the group with paraplegia.

Figure 3 shows the distributions of the subscale scores for the 5-AML items. The subscale scores differentiated between the tetraplegic and paraplegic groups and demonstrated significant change over time (all Mann–Whitney *U*-test results, $P<0.0001$; Friedman tests, $P<0.0001$). These results demonstrate good construct validity. Cronbach's alpha coefficients for the subscale scores were 0.89 (5-AML items), indicating good internal consistency. No extremes or outliers were present for the paraplegic group for the 5-AML subscale scores and relatively few for the tetraplegic group.

FIM mobility and locomotor items

The FIM mobility results are presented in Figure 4. The bed transfer item shows reasonable responsiveness over time for the paraplegic group but less so for the tetraplegic group. There is a clear ceiling effect of this item in the paraplegic group and a floor effect for the tetraplegic group. There appeared to be little difference between the three FIM mobility items for the paraplegic group.

The FIM locomotor items are presented in Figure 5. The items show severe restriction in range, both groups at all time points scoring either a 6 for the push/walk item (except for the tetraplegic group at baseline) or a 1 for the stair item. Neither item, therefore, discriminates between neurological impairment groups nor demonstrates changes in function over time.

Exploratory factor analysis

The three FIM mobility items and 5-AML items (eight items in total) were used for the exploratory factor analysis. The two FIM locomotor items were not suitable for use in this analysis because of the severe restriction in range. Although the study sample size was limited, an item to subject ratio of 1:5 was achieved, satisfying the minimum requirements for this type of analysis. The solution converged after eight iterations. Visual inspection of the scree plot and inspection of the initial eigenvalues indicated that a two factor solution was optimal, accounting for 80% of the variance.

The exploratory factor analysis identified a well-defined two-factor structure. The first factor to load contained the 5-AML items, with coefficients all above 0.63 (see Table 2). The second factor to load contained the three FIM mobility items, all loading with coefficients >0.86. These results suggest that there may be some item redundancy in the three FIM mobility items. Interestingly, the factor analysis indicated that it was appropriate to group the 5-AML items together.

Figure 6 shows the mean scores for the total scale using all eight items (ie, the 5-AML items and the three FIM mobility items) and demonstrates the utility of the whole scale for each group over different time points. The total scale shows adequate range across all time points for both groups, with occasional outlying values.

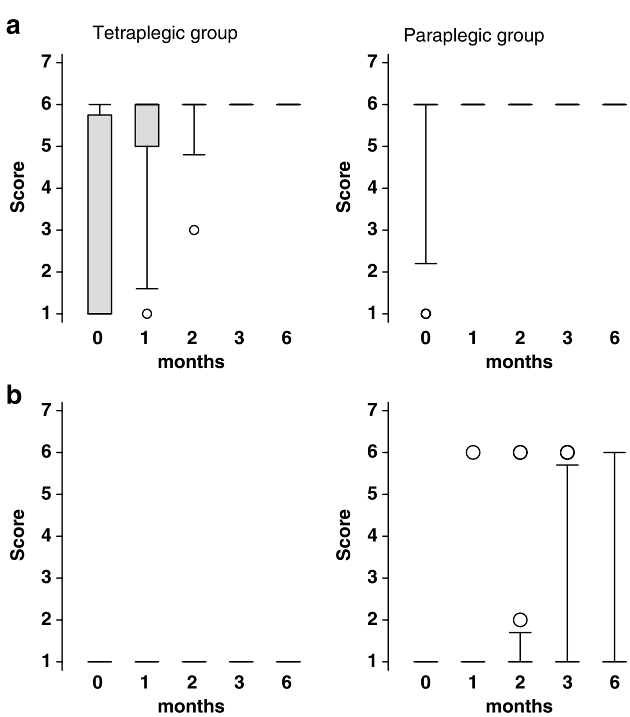

Figure 5 Boxplots for FIM locomotor items. (**a**) Push/walk item, (**b**) stair item

Discussion

The FIM is a useful global measure in rehabilitation due to its well-understood psychometric properties, good reliability and broad applicability to a wide range of impairment groups.[13] However, as a generic 'gold standard', evidence suggests it lacks some degree of specificity and sensitivity in certain functional domains for people with SCI. Previous research undertaken by our group[4] and others[3,9,25] has shown this to be most problematic for the locomotor, and to a lesser extent for the mobility items of the FIM. These limitations in the FIM need to be addressed, particularly in the current economic climate where funding is increasingly linked with outcomes.

Results of this study highlight the inherent problems of the two locomotor items of the FIM (ability to

Table 2 Rotated factor loading coefficient matrix

	Factor 1 (5-AML items)	*Factor 2 (FIM mobility items)*
AML – push on ramp	**0.923**	0.341
AML – push on flat	**0.851**	0.310
AML – bed transfer	**0.749**	0.360
AML – kerb ascent	**0.641**	0.240
AML – vertical transfer	**0.632**	0.426
FIM – toilet transfer	0.341	**0.928**
FIM – bath transfer	0.367	**0.914**
FIM – bed transfer	0.404	**0.862**

Bold values indicate items loading on each factor

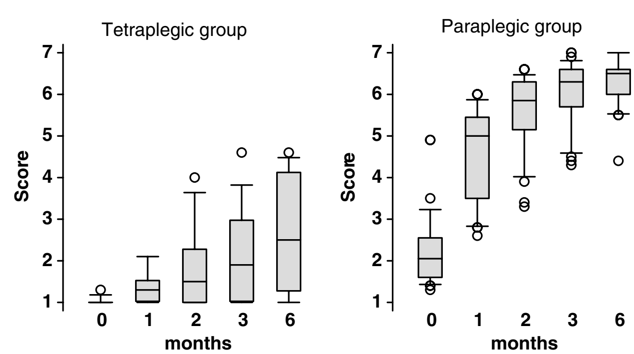

Figure 6 Boxplots for averaged score of the three FIM mobility and 5-AML items

mobilise on flat ground and ability to ascend stairs) for wheelchair-dependent individuals (see Figure 5). Neither item is sensitive to changes in function and neither item distinguishes between individuals with different neurological lesions. This is not surprising as most wheelchair-dependent patients are unable to negotiate stairs but able to traverse 50 m (either in a manual or electric wheelchair). Consequently, people with SCI (and ASIA grade A–C impairments) typically attain a score of 1 for the *stair item* and 6 for the *wheelchair locomotion* item. Hence, scores on the two locomotor items of the FIM are highly predictable and do not measure real-life aspects of people's ability to mobilise: aspects that are responsive to rehabilitation. These observations were confirmed statistically.

Addition of the three new, more challenging locomotor items provided good discrimination between the two major SCI impairment groups studied and was highly responsive to changes in function over time. Measurement of 'real world' activities, such as pushing a manual wheelchair over prolonged distances and negotiating inclines and kerbs, reflects upper limb function, fitness and skill, and not merely access to appropriate equipment (namely, an electric wheelchair). The *kerb* item was particularly responsive to change over time in the paraplegic group. Interestingly, there was a ceiling effect on the *flat push* item in the paraplegic group despite the requirement to push faster than the normal speed of walking for a maximal score. The *flat push* and *ramp* items were quite sensitive to change over time in the tetraplegic group.

The three FIM mobility items demonstrated a clear ceiling effect for the paraplegic group and a floor effect for the tetraplegic group (Figure 4). In addition, improvements made by individuals in one item were mirrored by improvements in the other two, although there was some suggestion that bed transfers were somewhat easier to perform than either toilet or tub transfers. This reflects the similarity in the three skills (that is the ability to move horizontally with assistance of equipment albeit onto different surfaces). Redundancy in these FIM items was evident with statistical analysis. These findings are in accordance with previous research by ourselves[4] and others,[13] and raises the question of the additive value of measuring three rather than one FIM mobility item in the SCI population.

Our two additional mobility items were selected in an attempt to overcome the floor and the ceiling effect of the three FIM mobility items found in persons with tetraplegia and paraplegia, respectively. Hence, the inclusion of a simple (ie bed mobility) and more complex (ie floor-to-wheelchair transfer) motor task. The *bed mobility* item showed enhanced responsiveness over time for persons with tetraplegia, however, had very limited utility in the paraplegic group which rapidly reached a ceiling. In a similar way, the *floor-to-wheelchair transfer* item involving vertical lifting effectively discriminated between the impairment groups, demonstrating enhanced responsiveness and reduced ceiling effect for persons with paraplegia. In fact, preliminary analysis showed that the floor-to-wheelchair transfer item could also discriminate effectively between individuals with high (T1–6) and low (T7 and below) paraplegia.

The factor analysis revealed that a combination of the three FIM mobility items and the 5-AML items provided the best overall result, indicating that the 5-AML items were measuring a slightly different construct from the FIM. However, the subscales were highly correlated with one another (~ 0.7) and one might question the value of administering both scales in this group of patients. Of course, a larger scale study is now required to validate these results and further refine the 5-AML items. It is generally agreed that studies of this nature should include 5–10 times as many subjects as there are items (in this case, up to 80 subjects[26]). However, fewer subjects may be acceptable if there is high loading of variables. This was the case in this study with several items loading at >0.8.[27]

The intention of the current paper was not to develop a new scale, but rather to explore the concept of enhancing certain less responsive domains of the FIM for individuals with SCI. This concept has been successfully adopted with the FAM in the traumatic brain injury population. While there are alternative scales that have recently been recommended for use in people with SCI, currently we believe that it is sensible to recommend a limited number of additional items that can be used in conjunction with the FIM to address some of its obvious limitations. The FIM is an internationally accepted and widely used tool. It adopts a simple scoring system that is readily understood. In certain domains, the FIM performs well for the SCI impairment group. For instance, there is an inverse relation between FIM self-care items and neurological level, as well as a consistent hierarchy of task difficulty.[4,28,29] This study has shown that the 5-AML items, used in conjunction with the FIM, can improve the ability to discriminate between impairments. In addition, the 5-AML is easy and quick to administer. Its scoring system is adapted from that of the FIM, thereby minimising the amount of staff training required. However, like any assessment tool, staff will require some familiarisation with the items.

The 5-AML was designed to overcome the perceived problems of the FIM motor items when used to assess changes in motor function of wheelchair-dependent persons. It was not designed to assess changes in motor function of ambulant patients. The FIM may already have reasonable responsiveness for this subgroup. For this reason, patients with ASIA D impairments and the potential to walk were excluded.

Further studies with sufficient sample size are necessary to formally assess reliability of 5-AML items and further assess discriminant validity and responsiveness across adjacent neurological levels, as well as to perform a full factor analysis of 5-AML with all FIM items included. It may also be possible in future studies to correlate mobility and locomotor outcomes with intensity and type of rehabilitation. Finally, items of the 5-AML have not been weighted according to their difficulty, so that a maximum score of 7 is gained for both easier and more difficult or for frequently or less frequently performed items. It is acknowledged that further research is required to justify the meaningful summation of item scores.

Conclusion

The 5-AML items enabled better discrimination between people with tetraplegia and paraplegia. The inclusion of simple and more difficult tasks also enhanced scale responsiveness with detection of clinically important changes in function over a 6-month rehabilitation period. The results of this study indicate that the three FIM mobility items used in conjunction with the 5-AML items provided an improved measure of mobility and locomotor function in wheelchair-dependent people with SCI than the FIM alone. These combined results provide strong support for construct validity of the 5-AML items.

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References

1 Hamilton BB, Granger CV, Sherwin FS, Zielezny M, Tahman JS. A uniform national data system for medical rehabilitation. In: Fuhrer MJ (ed). *Rehabilitation Outcomes: Analysis and Measurement*. PH Brookes Pub. Co.: Baltimore 1987, pp 137–147.
2 Ditunno JF, Young W, Donovan WH, Creasey G. The international standards booklet for neurological and functional classification of spinal cord injury. American Spinal Injuries Association. *Paraplegia* 1994; **32:** 70–80.
3 Dodds T, Martin D, Stolov W, Deyo R. A validation of the functional independence measurement and its performance among rehabilitation inpatients. *Arch Phys Med Rehabil* 1993; **74:** 531–536.
4 Middleton JW, Truman G, Geraghty TJ. Neurological level effect on the discharge functional status of spinal cord injured persons after rehabilitation. *Arch Phys Med Rehabil* 1998; **79:** 1428–1432.
5 Menter RR *et al*. Impairment, disability, handicap and medical expenses of persons aging with spinal cord injury. *Paraplegia* 1991; **29:** 613–619.
6 Ota T *et al*. Functional assessment of patients with spinal cord injury: measured by the motor score and the Functional Independence Measure. *Spinal Cord* 1996; **34:** 531–535.
7 Marino RJ, Huang M, Knight P, Herbison GJ, Ditunno JF, Segal M. Assessing selfcare status in quadriplegia: comparison of the quadriplegia index of function (QIF) and the functional independence measure (FIM). *Paraplegia* 1993; **31:** 225–233.
8 World Health Organisation. *International Classification of Functioning, Disability and Health: ICF Short Version*. WHO: Geneva 2001.
9 Catz A, Itzkovich M, Agranov E, Ring H, Tamir A. SCIM – spinal cord independence measure: a new disability scale for patients with spinal cord lesions. *Spinal Cord* 1997; **35:** 850–856.
10 Kirby R, Swuste J, Dupuis D, MacLeod D, Monroe R. The wheelchair skills test: a pilot study of new outcome measure. *Arch Phys Med Rehabil* 2002; **83:** 10–18.
11 Kilkens OJ, Post MW, van der Woude LH, Dallmeijer AJ, van den Heuvel WJ. The wheelchair circuit: reliability of a test to assess mobility in persons with spinal cord injuries. *Arch Phys Med Rehabil* 2002; **83:** 1783–1788.
12 Harvey L, Batty J, Fahey A. Reliability of a tool for assessing mobility in wheelchair-dependent paraplegics. *Spinal Cord* 1998; **36:** 427–431.
13 Stineman MG *et al*. The functional independence measure: tests of scaling assumptions, structure, and reliability across 20 diverse impairment categories. *Arch Phys Med Rehabil* 1996; **77:** 1101–1108.
14 Janssen TWJ, van Oers CAJM, Veeger HEJ, Hollander AP, van der Woude LHV, Rozendahl RH. Relationship between physical strain during standardised ADL tasks and physical capacity in men with spinal cord injuries. *Paraplegia* 1994; **32:** 844–859.
15 Norusis MJ. *SPSS for Windows: Professional Statistics*. SPSS Inc.: Chicago 1992.
16 Streiner DL. A checklist for evaluating the usefulness of rating scales. *Can J Psychiatry* 1993; **38:** 140–148.
17 Streiner DL. Figuring out factors: the use and misuse of factor analysis. *Can J Psychiatry* 1994; **39:** 135–140.
18 Gorsuch R. *Factor Analysis*. Saunders Company: London 1974.
19 Krzanowski WJ, Marriot FHC. *Multivariate Analysis*. Halsted Press: New York 1995.
20 Rummel RJ. *Applied Factor Analysis*. Northwestern University Press: Evanston 1970.
21 Cattell R. The scree test for the number of factors. *Multivariate Behav Res* 1966; **1:** 245–276.
22 Cronbach LJ. Coefficient alpha and the internal structure of tests. *Psychometrika* 1951; **16:** 297–334.
23 Nunnally JC. *Psychometric Theory*. 2nd edn McGraw Hill: New York 1978.
24 Siegel S. *Nonparametric Statistics for the Behavioral Sciences*. McGraw-Hill: New York 1956.
25 Catz A, Itzkovich M, Agranov E, Ring H, Tamir A. The spinal cord independence measure (SCIM): sensitivity to functional changes in subgroups of spinal cord lesion patients. *Spinal Cord* 2001; **39:** 97–100.
26 Comrey AL. Common methodological problems in factor analytic studies. *J Consuli Clin Psychol* 1978; **46:** 648–659.
27 Guadagnoli R, Velicer W. Relation of sample size to the stability of component patterns. *Psychol Bull* 1988; **103:** 1255–1263.
28 Granger C, Hamilton B, Linacre J, Heinemann A, Wright B. Performance profiles of the functional independence measure. *Am J Phys Med Rehabil* 1993; **72:** 84–89.
29 Heinemann AW, Magiera-Planey R, Schiro-Geist C, Gimines G. Mobility for persons with spinal cord injury: an evaluation of two systems. *Arch Phys Med Rehabil* 1987; **68:** 90–93.

APPENDIX

Task 1: Bed mobility

The task includes the following four elements:

- rolling onto one side (side determined by client)
- attaining a long sitting position from lying
- moving trunk from the centre of a gymnasium plinth to the edge of a gymnasium plinth in preparation for transferring
- moving legs from the centre of a gymnasium plinth to the edge of a gymnasium plinth in preparation for transferring

The patient starts in a lying position in the centre of a physiotherapy plinth. Patients are not to use assistive devices other than a slideboard for transferring. If a slideboard is used, the patient is scored one point lower. Time is irrelevant unless otherwise stated.

Score	*Level of independence*	*Performance scale*
7	Complete independence	The patient is able to perform all four elements of the activity independently and safely without assistive device/equipment and within a reasonable amount of time (<3 min for all four items of the task)
6	Modified independence	The patient requires more than 3 min to perform all four elements of the activity independently and safely
5	Supervision	The patient requires instruction or supervision but not physical assistance to complete all four elements of the activity. Time taken to complete the task is irrelevant
4	Minimal assistance	The patient is only able to perform three of the four elements of the activity independently and safely. Time taken to complete the task is irrelevant
3	Moderate assistance	The patient is able to perform two of the four elements of the activity independently and safely. Time taken to complete the task is irrelevant
2	Maximal assistance	The patient is able to perform one of the four elements of the activity independently and safely. Time taken to complete the task is irrelevant
1	Total assistance	The patient is unable to perform any of the four elements of the activity independently and safely

Task 2: Vertical transfer

The task involves the patient transferring from the floor back into their normal wheelchair (without cushion). The patient starts in the long sitting position with the wheelchair placed at an arm's length from either side of the patient. The patient can transfer into the wheelchair either sideways or backwards but not forwards. The task includes the following four elements:

- achieving the set-up position. This involves pulling the wheelchair close to the patient and positioning arms and legs ready for transfer
- lifting body first half of the vertical distance
- lifting body second half of the vertical distance
- moving bottom from landing position on the front edge of the wheelchair to finishing position with bottom back of the wheelchair

Patients are not to use assistive devices. Time is irrelevant unless otherwise stated.

Score	*Level of independence*	*Performance scale*
7	Complete independence	The patient is able to perform all four elements of the activity independently and safely without assistive device/equipment and within a reasonable amount of time (<3 min for all four items of the task)
6	Modified independence	The patient requires more than 3 min to perform all four elements of the activity independently and safely
5	Supervision	The patient requires instruction or supervision but not physical assistance to complete all four elements of the activity. Time taken to complete the task is irrelevant
4	Minimal assistance	The patient is only able to perform three of the four elements of the activity independently and safely. Time taken to complete the task is irrelevant
3	Moderate assistance	The patient is able to perform two of the four elements of the activity independently and safely. Time taken to complete the task is irrelevant
2	Maximal assistance	The patient is able to perform one of the four elements of the activity independently and safely. Time taken to complete the task is irrelevant
1	Total assistance	The patient is unable to perform any of the four elements of the activity independently and safely

Task 3: Push on the flat

The task involves the patient pushing a manual wheelchair on level ground (even concrete or asphalt). Two marks (eg cones) are placed 25 m apart. The patient is required to push from one mark, around the second mark and back to the original mark. Timing starts and finishes when the front wheels move past the first mark. One circuit is defined by 50 m.

Score	*Level of independence*	*Performance scale*
7	Complete independence	The patient is able to independently push 200 m in <1.5 min
6	Modified independence	The patient is able to independently push 200 m in <3 min
5	Supervision	The patient is able to independently push 100 m in <1.5 min
4	Minimal assistance	The patient is able to independently push 50 m in <45 s
3	Moderate assistance	The patient is able to independently push 25 m in <45 s
2	Maximal assistance	The patient is able to independently push 25 m in <2 min
1	Total assistance	The patient is unable to push 25 m in <2 min

Task 4: Push on the ramp

The task involves the patient pushing a manual wheelchair on two gradient ramps (steep – 1:14 and gentle – 1:20). Two marks (eg cones) are placed 15 m apart on the ramp. The patient is required to push up the ramp from one mark, around the second mark and back down the ramp to the original mark. Timing starts and finishes when the front wheels move past the first mark. One circuit is defined by 30 m up and down the ramp. Time is irrelevant unless otherwise stated.

Score	*Level of independence*	*Performance scale*
7	Complete independence	The patient is able to independently push up AND down the 1:14 (steep) ramp in <30 s
6	Modified independence	The patient is able to independently push up AND down the 1:14 (steep) ramp in <1 min
5	Supervision	The patient is able to independently push up AND down the 1:14 (steep) ramp but takes >1 min
4	Minimal assistance	The patient is able to independently push up OR down the 1:14 (steep) ramp. The patient must also be able to independently push up AND down the 1:20 (gentle) ramp
3	Moderate assistance	The patient is able to independently push up AND down the 1:20 (gentle) ramp
2	Maximal assistance	The patient is able to independently push up OR down the 1:20 (gentle) ramp
1	Total assistance	The patient is unable to independently push up OR down the 1:20 (gentle) ramp

Task 5: Negotiate kerbs

The task involves the patient pushing up small (2.5 cm) and large (15 cm) kerbs. The task requires the patient to start below the kerb, push up the kerb and finish above the kerb. The patient can approach the kerb with speed if required.

Score	*Level of independence*	*Performance scale*
7	Complete independence	The patient is able to independently push up a large kerb
6	Modified independence	The patient is able to push up a large kerb with supervision
5	Supervision	The patient is able to push up a large kerb with minimal assistance
4	Minimal assistance	The patient is able to get the front wheels of the wheelchair up on a large kerb and pull up the kerb with a pole
3	Moderate assistance	The patient is able to get the front wheels of the wheelchair up on a large kerb
2	Maximal assistance	The patient is able to independently push up a small kerb
1	Total assistance	The patient is unable to unable to independently push up a small kerb