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RELATIONSHIPS BETWEEN INDEPENDENCE LEVEL OF SINGLE MOTOR-FIM ITEMS AND FIM-MOTOR SCORES IN PATIENTS WITH HEMIPLEGIA AFTER STROKE: AN ORDINAL LOGISTIC MODELLING STUDY

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Objective: **To assess the relationships between independence levels of single motor-related Functional Independence Measure (FIM™) items and summed FIM-motor scores of patients with hemiplegia after stroke.**

Design: **For each patient FIM scores were assessed 4 times during hospitalization. Ordinal logistic analyses were performed on group data.**

Subjects: **Fifty patients with hemiplegia after stroke staying in a long-term rehabilitation facility.**

Results: **Analyses revealed that FIM-motor scores accounted for much of the variability of independence levels for most of the single FIM™ items, including dressing upper body, and transfers to bed/chair/wheelchair and to toilet. For these items, the independence levels were proportionally associated with FIM-motor scores. For eating, higher FIM-motor scores ($>$ 60) were associated with modified independence and lower FIM-motor scores ($<$ 40) correlated with attainment of supervision/set-up levels. For dressing lower body, greater independence was apparent when FIM-motor scores were higher ($>$ 60).**

Conclusion: **For single FIM™ items, relative difficulty was comparable with results from previous literatures using Rasch analyses. Moreover, our results revealed that relative difficulty for single items varied greatly between independence levels. With regard to disability task targets, probability of independence evaluated from logistic modelling is an aid to efficient rehabilitation scheduling.**

Key words: Probability, prognosis, recovery, stroke.

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INTRODUCTION

Several lines of evidence have indicated that the physical disabilities of stroke patients with hemiplegia after stroke show similar patterns of recovery (1–4). Using Rasch analyses, previous studies have characterized such patterns with reference to physical disability evaluated by FIM™. More easily accomplished activities include eating, grooming, bowel and bladder management; more challenging activities extend to dressing lower body, bathing, locomotion, transfers to tub/shower, and stair climbing; in between, intermediate activities are dressing upper body, toileting, and transfers to bed/chair/wheelchair (5, 6). Indeed, the recovery from physical disability for any given patient after stroke can usefully be evaluated in terms of "item difficulties" criteria (5).

Treatment of an individual patient optimally involves a rehabilitation team consisting of physiatrists, nursing staff, occupational, physical, and speech therapists, who work according to a therapeutic regimen tailored to facilitate functional independence in daily living. Consequently, knowledge of typical recovery patterns should contribute to more efficient rehabilitation and nursing care. As yet, there has been little information concerning the variability of recovery from physical disability: some stroke patients, from an early stage, show continuously slow recovery for a particular physical disability (e.g. grooming), while accelerated recovery from other physical disabilities (e.g. dressing lower body) occurs during the latter stages towards final outcome. It would be more efficient, and less frustrating for the patient, to time rehabilitation at the appropriate stage in individual recovery by focusing on particular attainable targets, including rehabilitative training, such as toilet use. Since the "item difficulties" concept is unidimensional, it is not very helpful in making these clinically important decisions because no allowance is made for variability.

In this study, we undertook further investigation of variability in the performance profiles of motor-related FIM™ items by applying logistic modelling to data collected from a wide variety of patients with hemiplegia after stroke.

METHODS

Patients

We recruited patients with hemiplegia after stroke who were admitted to our long-term rehabilitation hospital during the period August 2003 to July 2005. Criteria for inclusion were: no past history of hemiplegia; functional independence in daily living before stroke; wheelchair required for locomotion at admission. To minimize variability in the therapeutic regimen, we limited recruitment in this study to patients who received treatment from a rehabilitation team directed by a single

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physiatrist (first author of this article). The protocol was reviewed and approved by our hospital's ethical committee and informed consent was obtained from all patients. In line with Japanese health insurance procedures, typically at 30–60 days after the stroke occurred, patients were referred from local community acute medical services and subsequently received in-patient care in our long-term rehabilitation hospital for 30–180 days. During hospitalization, patients underwent physical therapy, occupational therapy and speech therapy for a combined daily total of 120 minutes.

FIM™ measurements

FIM™ tallies 18 items for daily living, which are graded on a 7-point scale: 1 = total assistance; 2 = maximal assistance; 3 = moderate assistance; 4 = minimal contact assistance; 5 = supervision or set-up; 6 = modified independence; and 7 = complete independence (7). The items fall into 6 categories. Four involve motor functions (FIM-motor): self-care – eating, grooming, bathing, dressing upper body, dressing lower body, toileting; sphincter control – bladder management and bowel management; mobility – transfers to bed/chair/wheelchair, transfers to toilet, transfers to tub/shower; locomotion – walking or wheelchair propulsion, stair climbing. The other 2 categories involve the cognitive functions (FIM-cognition) of communication – comprehension and expression, and social cognition – social interaction, problem solving, and memory. In rehabilitation medicine, the subtotal-summation scores of motor and cognitive components (FIM-motor and FIM-cognition) are commonly used to quantify functional independence. Using FIM™ scores, nursing staff assessed the functional recovery of patients. To ensure that the evaluations were reliably consistent, FIM™ scores were reviewed at weekly conferences and assured by the agreement, across the scores, of 2–4 raters.

Evaluations were typically recorded a few days after admission, again at 2–6 weeks after admission, and then once a month during hospitalization. In this study we analysed the scores entered in the database for the first 3 assessments during hospitalization and for the final assessment.

Data analysis

To determine the association between FIM-motor scores (explanatory variable) and independence level for single FIM™ items within motor components (dependent variable), ordinal logistic modelling analysis was used (8).

The principle of logistic modelling is fitting the probability (p) of a dichotomous response (such as "yes/no" or "dead/alive") to a linear model. Probability odds for such dichotomous response, $p/(1-p)$ can take any positive value. The logarithm of these odds is modelled as a simple regression and parameter estimates are assessed for fit to the model:

$$\log [p/(1-p)] = \alpha + \beta X$$

(α, constant; β, coefficient; X, explanatory variable)

To extend the utility for multi-level ordinal responses, cumulative probability is calculated at each level to model the odds to a simple regression. Taking, for example, three-level responses (p_1, p_2, p_3; summation equals 1), the logarithm of the odds are modelled as 2 simple regressions for the three-level responses and parameter estimates are assessed for fit to model (note that single β and 2 levels of α are to be assessed).

$$\log [p_1/(p_2 + p_3)] = \alpha_1 + \beta_1 X$$

$$\log [(p_1 + p_2)/ p_3] = \alpha_2 + \beta_1 X$$

In this study, the probability of 7 independence levels for single FIM™ items were evaluated in relationship with FIM-motor scores. Analyses for all the subjects in the sample population were performed on data from each of the 4 sampling time-points. Goodness-of-fit of logistic modelling was assessed by Wald χ^2 testing ($p < 0.001$). All statistical analyses were performed using the JMP software package (SAS Institute, Cary, NC, USA).

RESULTS

Patients and data samplings

We gathered data from 50 patients (Table I). As can be seen, the patients in our population varied widely in terms of age, site of lesion, and affected hemisphere. Fig. 1 shows the time course for the FIM™ scores of typical cases. These show rapid recovery during the first few months, and a subsequently slower rate of recovery towards the final outcome. Close observation of time courses showed that the major contributors to recovery were the motor components (FIM-motor). In sharp contrast, cognitive components (FIM-cognition) changed slightly. Fig. 2 is a box-chart summarizing the group data for FIM-motor scores for the first to fourth sampling time-points (each $n = 50$). The time series for overall FIM-motor scores showed a typical recovery pattern (dashed line in Fig. 2) comparable to that in individual examples (Fig. 1). FIM-motor scores for individual patients ranged from 14 to 83 while the sampling day from stroke onset ranged from 17 to 236: in other words, the patient sample encompassed, with regard to both physical disability and duration, wide-ranging states of stroke recovery.

Relationships between independence levels of single FIM™ items and FIM-motor scores

Fig. 3 and Table II show results obtained from ordinal logistic modelling of the data-set. Scores for locomotion were derived from the item for walking or wheelchair propulsion. Stair

Table I. *Patient characteristics ($n = 50$)*

Patient characteristic		n
Gender	Male	29
	Female	21
Age (years)		33–89 (median, 69)
Lesion hemisphere	Right	25
	Left	25
Lesion site	Putamen	15
	Thalamus	9
	Corona radiata	7
	MCA	7
	Frontal lobe	6
	ICA	4
	Occipital lobe	1
	Temporal lobe	1
Lesion type	Haemorrhage	26
	Infarct	24
Acute treatment	Conservative	39
	Operative	11
Co-morbidity	Hypertension	26
	Diabetes mellitus	9
	Atrial fibrillation	7
	CAD	5
	Hyperlipidaemia	5
	Alcoholism	2
	Other	2
Total		50

MCA = occlusion of middle cerebral artery; ICA = occlusion of internal carotid artery; CAD = coronary artery disease; Other co-morbidity = comprised hepatic cell carcinoma (post-operative) and abdominal aortic aneurysm (post-operative).

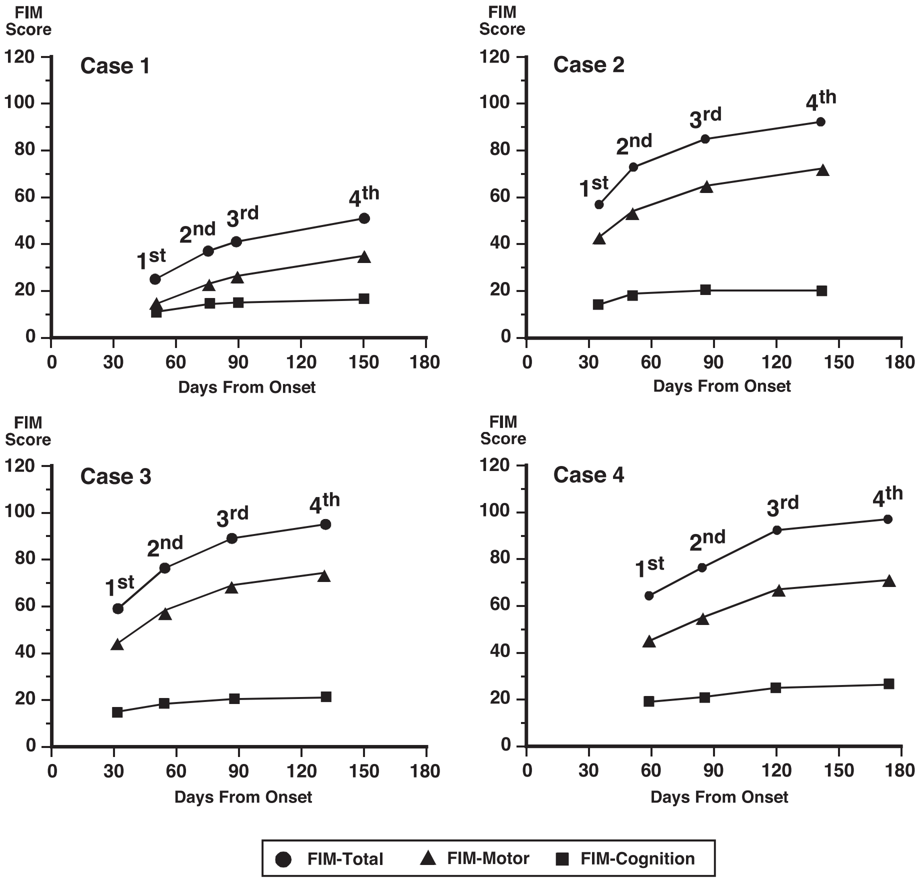

Fig. 1. Time course of FIM™ scores for typical cases (cases 1–4). Closed circles =FIM-total scores; closed triangles =FIM-motor scores; closed squares =FIM-cognition scores. Case 1: a 63-year-old female patient with a left putamen haemorrhage. Case 2: a 48-year-old male patient with occlusion of left internal carotid artery. Case 3: a 69-year-old male patient with a left frontal lobe infarct. Case 4: a 54-year-old male patient with occlusion of left internal carotid artery.

climbing was excluded from evaluation because, for safety reasons, our hospital prohibits patients from using stairs.

For each single FIM™ item, the fit of ordinal logistic modelling was statistically significant, indicating that the results in the data-set could be validly interpreted as logistic probability. Logistic curves for dressing upper and lower body, transfers to bed/chair/wheelchair, and to toilet were steep, while those for transfers to tub/shower and locomotion were less steep. When logistic curves are steep, FIM-motor scores account for a large proportion of the variability in the performance levels of the particular single FIM™ item being tested. Accordingly, statistical analysis yielded a more evident model fit (indexed by R^2) for these items. In contrast, the width of the curves indicates how well FIM-motor scores associate with performance level improvements in the particular FIM™ item being tested.

For dressing upper body, transfers to bed/chair/wheelchair and to toilet data showed similar patterns: 6 steep logistic curves evenly distributed across the entire range of the horizontal axis (FIM-motor scores). Such patterns indicate that independence levels within these single FIM™ items are proportionally associated with FIM-motor scores. Data for eating showed a unique pattern with a wide range for independence level 5 (supervision or set-up). This indicated that patients after stroke could easily reach supervised or set-up levels for eating, but that higher levels (modified or complete independence) were much more difficult to attain. Similarly, data for bowel management exhibited a pattern with a wide range for independence level 6 (modified independence). These results reflect a general weakness of abdominal muscles among patients after stroke and a consequent need to treat constipation with laxatives. Data for dressing lower body showed a characteristic pattern of curves distributed high along the horizontal axis. This indicated that, while only minimal improvements in independence levels could be expected when FIM-motor scores were low (<40), when FIM-motor scores were high (>60), small increases in FIM-motor scores would lead to a major improvement in independence levels. Data for locomotion and transfers to tub/shower exhibited less steep curves, indicating that independence levels of these single FIM™ items were less closely associated with FIM-motor scores. As shown, the relationships between FIM-motor scores and independence levels of single FIM™ items varied greatly.

Fig. 4 shows FIM-motor values that predicted a 50% probability of at least independence level 5 (supervision or set-up) for each FIM-motor item. To reach at least 50% probability

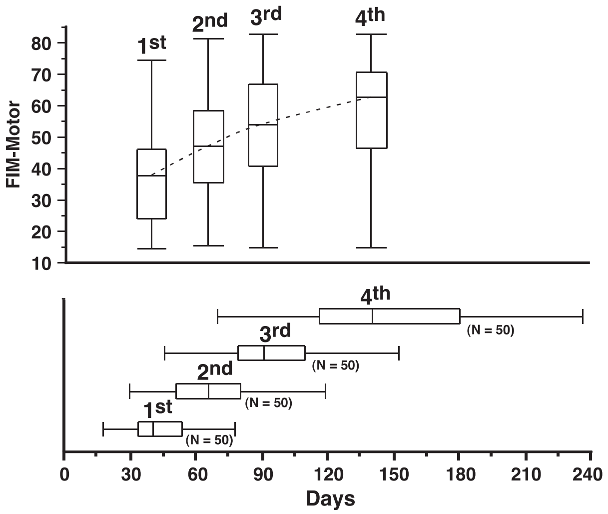

Fig. 2. Box-chart summary of group data for FIM-motor scores and sampling time-points (1st to 4th, $n = 50$ each). The middle line in the box indicates the median. The ends of the box are the 25% and 75% values. The bars represent ranges of data distribution.

for level 5, lower FIM-motor scores (<40) were sufficient for eating and grooming, but higher FIM-motor scores (> 60) were needed for bathing and transfers to tub/shower.

DISCUSSION

Several lines of research have characterized the relative difficulties among motor-related single FIM™ items of patients with hemiplegia after stroke (5, 6, 9). Few studies, however, have systemically analysed the relative difficulties between independence levels within single FIM™ items. Using ordinal logistic modelling, in this study, we have been able to detect independence probabilities for single FIM™ items in relationship to FIM-motor scores.

Rationale for using logistic modelling

FIM™ assessment was originally applied on an ordinal rather than an interval scale. In this study, however, following numerous previous studies that have extensively and successfully analysed FIM-motor scores as interval values (10–12), we treated FIM-motor scores as interval-scaled data. Accordingly, working with FIM-motor scores (interval scale) as the explanatory variable, and levels of single FIM™ items (ordinal scale) as dependent variables, we performed ordinal logistic analyses. Results from logistic modelling were successful for all analyses, indicating that the association could be properly interpreted as logistic probability.

A sceptic may object that tautology is present in our analyses; independence levels of single FIM™ items, a breakdown of the FIM-motor score, is correlated with FIM-motor scores. To test the relevance of this issue, we performed preliminary analyses using summed scores with the targeted single item excluded. The results differed minimally from the present Fig. 3. Accordingly, to allow better clinical applicability, we preferred to employ analyses using FIM-motor scores. There may also be other concerns about group analyses in which within-subject variability and between-subject variability are taken together. Testing this, results from our preliminary analysis of the separate data from each time point (1st to 4th) measurement did not disagree with our conclusion. Accordingly, to achieve sufficient statistical power, in the final analyses we employed the group data.

Relative difficulties of motor-related FIM™ items

Comparable to the results indicated by Rasch analysis (5), the present study has shown varying difficulties for different motor-related FIM™ items of patients with hemiplegia after stroke; improvements in eating, grooming, and bowel management came more easily; greater independence in dressing lower body, transfers to tub/shower, and bathing were harder to achieve (Fig. 4). Going further than conclusions from Rasch analysis, our different analytical procedure was able to shed light on relative difficulties of performance within single items. For example, our analysis of data for eating showed that, although patients after stroke could easily reach supervision or set-up levels, modified or complete levels of independence were much more difficult to attain (Fig. 3). Even though the association of FIM-motor scores with supervision or set-up levels were nearly equal for dressing upper body and dressing lower body (Fig. 4), the relative difficulty in attaining given levels within these single items showed different patterns: independence levels within dressing upper body improved in proportion to FIM-motor scores, while improved levels within dressing lower body were associated with higher FIM-motor scores (Fig. 3). Such findings suggest that ordinal logistic modelling is a viable alternative for examining patient performance status, particularly when the relative difficulty of attaining given independence levels within a particular physical ability is in question.

Independence levels of single FIM™ items relative to FIM-motor scores

FIM-motor scores accounted for much of the variability in independence levels for transfers to bed/chair/wheelchair and to toilet (see Fig. 3). For these FIM™ items, as shown in Fig. 3, the independence levels changed in proportion to FIM-motor scores. Accordingly, levels of independence for these items may predict general physical independence for patients after stroke. This may be useful for prompt first-visit screening of patients and in other clinical situations. By contrast, FIM-motor scores had less relevance to the variability of independence levels for transfers to tub/shower and locomotion. These findings tally with a previous study that reported that the relationships between summed FIM™ scores and single FIM™ items were multidimensional rather than unidimensional (9).

In contrast to a previous report (5), our analysis indicated that locomotion was easier than transfers. This discrepancy is likely due to treating both walking and wheelchair propulsion as locomotion and the subsequent inclusion of a large proportion of wheelchair users in our study. As a result, for the majority of

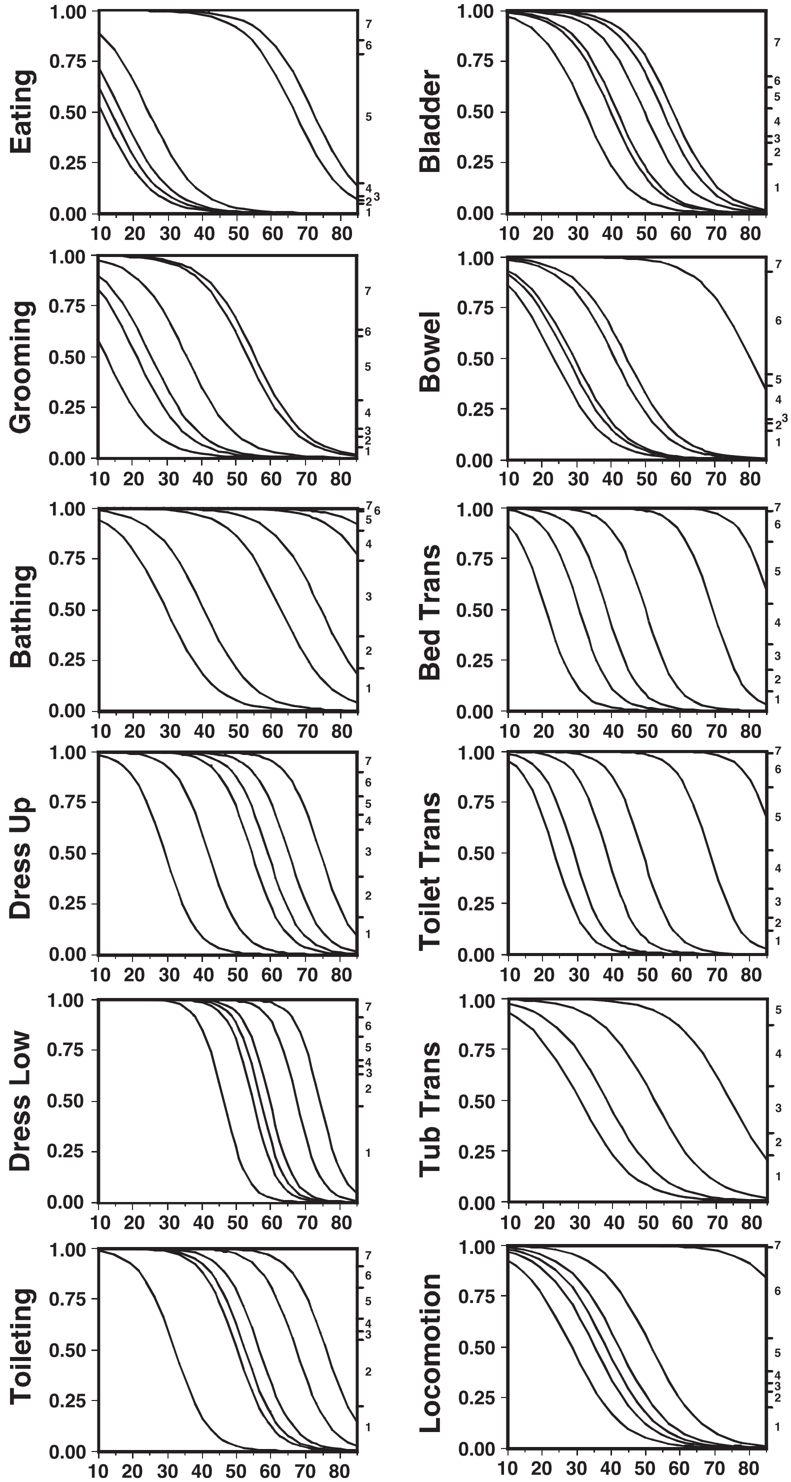

Fig. 3. Logistic probability plots of relationship between FIM-motor scores and independent levels of single motor FIM™ items (group data, total $n = 200$). Left vertical axis shows logistic probability and horizontal axis shows FIM-motor scores. The first (bottom) curve shows the probability attributed to level 1. The next higher curve shows the probability attributed to level 2. Thus, the distance between the first 2 curves is the probability for level 2. The distance from the top curve to the top of the graph is the probability attributed to level 7 (level 5 for Tub Trans). At each FIM-motor value, the probability scale in the vertical axis is divided (partitioned) into probabilities for each response category (indexed by right vertical axis). The probabilities are measured as the vertical distance between the curves, with the total across all vertical category probabilities summing to 1. Dress Up = dressing upper body; Dress Low = dressing lower body; Bed Trans = transfers to bed/chair/wheelchair; Toilet Trans = transfers to toilet; Tub Trans = transfers to tub/shower. Locomotion data include scores for walking or wheelchair propulsion.

Table II. *Parameter estimates for logistic equations*

	β	α						R^2
		Ordinal logistics (independence level of FIM™ item)						
		1	2	3	4	5	6	
Eating	−0.1423	1.5608	1.9329	2.3684	3.4951	9.5006	10.2657	0.3110
Grooming	−0.1414	1.7574	3.0227	3.6183	5.0741	7.5682	7.8845	0.3050
Bathing	−0.1417	4.1960	5.7489	8.9157	10.5644	13.2733	14.4868	0.3112
Dress Up	−0.2129	6.2514	8.9555	11.6334	12.6174	13.8967	15.8600	0.4082
Dress Low	−0.2848	13.2465	15.6689	16.3103	17.0360	19.2687	21.1961	0.4831
Toileting	−0.2005	6.4348	10.0838	10.5434	11.3767	13.5103	15.2718	0.3976
Bladder	−0.1517	4.9386	6.0908	6.3853	7.5706	8.4040	8.8441	0.3072
Bowel	−0.1359	3.1989	3.7347	4.0001	5.6046	6.0845	10.9284	0.2826
Bed Trans	−0.2172	4.5633	6.6698	8.4174	10.8424	15.0665	18.8667	0.4363
Toilet Trans	−0.2240	5.2690	6.5253	8.6726	10.9834	15.3265	19.7896	0.4506
Tub Trans	−0.1254	3.8293	4.8245	6.5581	9.3039	–	–	0.2761
Locomotion	−0.1352	3.8693	4.7731	5.2226	5.7291	6.9879	13.1551	0.2787

All logistic regression analyses were statistically significant (χ^2, $p > 0.0001$). Dress Up = dressing upper body; Dress Low = dressing lower body; Bed Trans = transfers to bed/chair/wheelchair; Toilet Trans = transfers to toilet; Tub Trans = transfers to tub/shower. Data for Locomotion include scores for walking or wheelchair propulsion.

cases, the locomotion data in the analysis were derived from wheelchair propulsion rather than walking. The discrepancy in findings may also have arisen, in part, by differences between the studies in treatment focus and in the disability levels of the patients.

Patterns of functional recovery

To outline patterns of recovery in the time course, we sampled FIM™ assessment 4 times per subject. As shown in Fig. 2 and Table I, we collected data from a wide variety of patients during various recovery stages. Even so, overall recovery patterns were consistent for both the overall population and its individual members: rapid initial recovery that slowed towards final outcome (3, 13–15). As in our previous findings, during 1–6 months after stroke onset, physical disability recovery was far greater than cognitive disability recovery (15). Knowledge of such predictable recovery patterns combined with focused prediction derived from logistic modelling (Fig. 3) may provide confident prognosis that is reassuring to individual patients. Meanwhile prediction of the attainable recovery of physical abilities may allow caregivers to make better allowance for lifestyle after discharge.

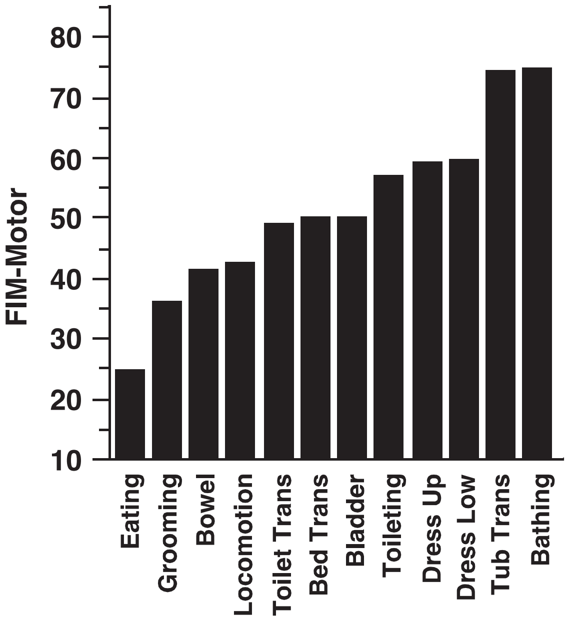

Fig. 4. FIM-motor scores that reached 50% probability of at least independence level 5 (supervision or set-up) for single FIM™ items. Data were derived from the logistic analyses shown in Fig. 3. Dress Up = dressing upper body; Dress Low = dressing lower body; Bed Trans = transfers to bed/chair/wheelchair; Toilet Trans = transfers to toilet; Tub Trans = transfers to tub/shower.

Clinical applicability

Using ordinal logistic modelling, we have revealed probability distributions for single FIM™ items relative to FIM-motor scores. Results, as shown in Fig. 3, could serve as useful tool for scheduling when planning rehabilitative therapies and nursing care for groups of similar patients. For example, when the FIM-motor scores for patients are around 20, it would be most beneficial to focus on rehabilitative training for eating and grooming: training for bathing, dressing, and toileting would most likely result in frustration for most patients at this stage. Later, when the FIM-motor score reaches around 30, the focus of rehabilitation might shift to transfers and bowel management. When the FIM-motor score reaches around 50, it would be appropriate to start training for dressing lower body. Comparison of personal scores with those shown in Fig. 3 makes it possible to tailor individual training with targets that more closely matched achievable levels for specific physical abilities. In this way, rehabilitative regimen can be designed with allowance for variability in the independence levels of physical abilities.

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