A factor analysis of Functional Independence and Functional Assessment Measure scores among focal and diffuse brain injury patients: The importance of bi-factor models.

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This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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Structured Abstract

Objective: To explore the factor structure of the UK Functional Independence Measure and Functional Assessment Measure (FIM+FAM) among focal and diffuse acquired brain injury patients.

Design: Criterion standard.

Setting: An NHS acute acquired brain injury inpatient rehabilitation hospital.

Participants: Referred sample of 447 adults (835 cases after exclusions) admitted for inpatient treatment following an acquired brain injury significant enough to justify intensive inpatient neurorehabilitation.

Intervention: Not applicable.

Outcome measure: Functional Independence Measure and Functional Assessment Measure.

Results: Exploratory Factor Analysis suggested a two-factor structure to FIM+FAM scores, among both focal-proximate and diffuse-proximate acquired brain injury aetiologies. Confirmatory Factor Analysis suggested a three-factor bi-factor structure presented the best fit of the FIM+FAM score data across both aetiologies. However, across both analyses, a convergence was found towards a general factor, demonstrated by high correlations between factors in the Exploratory Factor Analysis, and by a general factor explaining the majority of the variance in scores on Confirmatory Factor Analysis.

Conclusion: Our findings suggested that although factors describing specific functional domains can be derived from FIM+FAM item scores, there is a convergence towards a single factor describing overall functioning. This single factor informs the specific group factors (e.g. motor, psychosocial and communication function) following brain injury. Further

research into the comparative value of the general and group factors as evaluative/prognostic measures is indicated.

Keywords: brain injuries; rehabilitation; treatment outcome; factor analysis

Abbreviations:

Acquired Brain Injury (ABI)

Comparative Fit Index (CFI)

Confirmatory Factor Analysis (CFA)

Exploratory Factor Analysis (EFA)

Functional Independence Measure and Functional Assessment Measure (FIM+FAM).

Keiser–Meyer–Olkin (KMO)

Non-normed fit index (NNFI)

Relative chi-square degrees of freedom (CMIN/DF)

Root mean square of approximation (RMSEA)

Standardised root mean square residual (SRMR)

Patients with moderate to severe acquired brain injury (ABI) may experience long-lasting or permanent difficulties with mobility, activities of daily living, cognition and social reintegration[1]. Accurate functional assessments enable interdisciplinary teams to set meaningful rehabilitation goals, make better predictions about prognosis, and identify appropriate discharge placements earlier in rehabilitation[2,3].

The UK Functional Independence Measure and Functional Assessment Measure (FIM+FAM[4]) is used in complex ABI rehabilitation services UK-wide and internationally. It evaluates functional impairment and assistance needs across physical, communication and psychosocial domains, using input from the interdisciplinary therapeutic team. The FIM+FAM is a reliable, valid scale with high internal consistency, excellent test-retest reliability and very good inter-rater reliability, and is one of the most widely-used outcome measures in ABI rehabilitation[2,4–7]. However, conflicting arguments have been advanced regarding the structure of the FIM+FAM, affecting its interpretation and prognostic utility.

Initial key research supported a two-factor FIM+FAM structure, comprising a motor and cognitive subscale as per the manual[8,9]. However, further work suggested a greater number of factors may better explain the variance in scores. For example, among a general neurorehabilitation sample, a four-factor FIM+FAM structure was identified incorporating a motor factor (comprising 15 of the 16 original motor items), subdivision of the cognitive scale into psychosocial (9 items, e.g. social interaction and emotional status) and communication elements (5 items, e.g. comprehension and expression), and the final factor comprised 6 activities of daily living items, plus the community mobility item formerly viewed as part of the motor subscale[10]. Similarly, among stroke patients a three-factor structure was identified comprising 15 of the 16 original motor items (excluding swallowing),

and the same division into psychosocial and communication factors; this was superior to the two-factor model comprising motor items and the broader cognitive factor[11].

These analyses indicate the validity of a multifactorial interpretation of the FIM+FAM, with factor structures demonstrating specific and independent dimensions of function identifiable on assessment following ABI[7]. However, both of the aforementioned studies also reported salient loading of the FIM+FAM items onto a single component; this suggests a potential additional use of the scale as a measure of general functioning, aside from the more faceted multifactorial solutions[7]. This implies the possible validity of a bi-factor model solution, which integrates single and multiple factor solutions. This enables retention of a single common construct (e.g. general functional independence), while also acknowledging multidimensionality (e.g. motor, psychosocial and communication group factors)[12]. However, previous examinations of potential factor structures of the FIM+FAM have not considered a potential bi-factor model[7,11].

The division of the FIM+FAM into multiple factors of function is also worth exploring in the context of varied injury aetiologies, which can present differently clinically and thus differentially influence prognosis, care management and rehabilitative input. For example, previous research FIM+FAM research found different functional outcomes between right- and left-sided stroke patients[11]. Similar differences may exist between the effects of focal and diffuse brain injury. Focal injury is generally limited to a smaller, more defined area and is typically associated with greater physical impairment and fewer cognitive effects, whereas patients with diffuse injuries often retain more physical function, but with greater cognitive impairment (particularly regarding communication and psychosocial functions)[13,14]. However, many ABI comprise elements of both (e.g. diffuse axonal injury resulting from

trauma, or sub-arachnoid strokes may cause diffuse injury despite initiating as a focal bleed[11]) and might best be described as diffuse-proximate and focal-proximate.

Currently, no study has explored the various multifactorial explanations of the FIM+FAM while comparing these two main ABI groupings, nor have they explored the structure of FIM+FAM scores in terms of the potential validity of bi-factor models. This study therefore aimed to explore the factor structure of the FIM+FAM, including testing of a bi-factor conceptualisation, among focal-proximate and diffuse-proximate brain injury patients.

Method

Sample

Data were collected from 447 complex ABI inpatients (290 males, 157 females). The mean sample age on admission was 47.55 years (*SD*=14.81, range 16-83 years). The sample comprised all patients (with exclusions, below) who were admitted for NHS tertiary specialist rehabilitation between 12/08/2008 and 20/02/2017. All participants met the national criteria for NHS Level 1 complex tertiary inpatient rehabilitation in the United Kingdom; i.e. they had complex nursing, medical and therapeutic needs requiring specialist clinical management[5,15]. The data included patients who were discharged due to acute ill health/death. Exclusion criteria comprised patients who were discharged within a week (generally because their needs were insufficiently complex to require inpatient care, or because they were too

unwell to engage in rehabilitation). Patients were also excluded who had a non-ABI diagnosis (e.g. pain syndromes, psychiatric disorders or severe physical trauma not involving the brain), progressive conditions (e.g. multiple sclerosis), or other rare conditions where inclusion would have compromised patient anonymity.

The overall sample composition in terms of injury type was 40% trauma, 37.4% stroke, 14.1% anoxia, 5.1% inflammatory condition and 3.4% tumour (or injury by tumour removal). In terms of localisation, for 6.2% of patients, injury location had not been documented and these cases were therefore not included in analysis. Of the remainder, 49.4% of patients had sustained global, diffuse or bilateral-hemisphere injury and 50.6% had sustained a localised injury to the frontal region, the brainstem/cerebellum, or the left/right hemisphere.

Measure

All inpatients were assessed for cognitive and functional impairments using the 36-item English-language FIM+FAM on admission and discharge[9], comprising assessments of self-care, mobility, communication, cognition, mood and social behaviour. Each patient's admission FIM+FAM was completed by an interdisciplinary team (allocated consultant, clinical psychologist, physiotherapist, occupational therapist, speech and language therapist and dietitian) meeting two weeks post-admission, describing the patient's impairment/function on arrival. The follow-up FIM+FAM was completed at the first weekly meeting post-discharge. Most FIM+FAM items are scored between 1-7 (except item 14.2,

wheelchair locomotion, which is scored 0-6; 0 indicates that the patient never requires a wheelchair), with 7 indicating total independence and decreasing scores indicating greater impairment. Demographic and aetiological data were collected from medical records.

The "Extended Activities of Daily Living" section (items 31-36)[6] was excluded from this analysis because it had been inconsistently completed over the years. 80.6% (5734/7111) of ratings were scored at 1, which is both the lowest score possible and the default rating when assessment had not yet been completed, with no means to differentiate between which scores were accurate and which were placeholders.

Data Preparation, Missing Values and Analysis

Consistent with previous research[7], we included FIM+FAM scores acquired upon participants' admission and discharge to maximise the range of scores sampled across the population. This increased the sample size to n=894. However, some cases were removed. Seven cases were removed as the UK FIM+FAM allows a '0' score for wheelchair locomotion if a wheelchair is never used, making this data incongruous with the rest of the scoring. Fifty-two cases were removed due to missing injury localisation data. 835 cases were taken forward, from which 420 cases had a focal-proximate brain injury (stroke or trauma) and 415 cases had a diffuse-proximate brain injury (anoxia or inflammatory condition).

Ethics

The South Warwickshire NHS Clinical Audit and Effectiveness Department (registration: 1400) and the University of Leicester (reference 9256) provided approval. Full ethical board review was not required, since no additional data were collected.

Results

Exploratory Factor Analysis (EFA) is used to discover the underlying structure of items within a data set. Confirmatory Factor Analysis (CFA) is used to test whether proposed structures to a set of items provide a good explanation of the data. No previous research has reported on the factor structure for FIM+FAM item scores among focal-proximate and diffuse-proximate brain-injured individuals, and the clinical presentation of symptoms is complex. Therefore, we subjected the data to both EFA (to discover the underlying structure of the items) and CFA (to test possible structures to the set of items). Accordingly, after removing missing cases, we divided both the focal-proximate and diffuse-proximate participant data into two samples (focal-proximate, *n*=210/210; diffuse-proximate, *n*=207/208) using SPSS for Windows™ randomly-generated numbers to place participants in a random order and assign them to the EFA or CFA sample.

Exploratory Factor Analysis

Across the focal-proximate and diffuse-proximate data used for EFA, the ranges for skewness and kurtosis statistics for the 30 FIM+FAM items fell between -1.25 to 1.46 (skewness) and -1.91 to 0.36 (kurtosis). These statistics fall within criteria of values within +/-2 representing "acceptable" symmetry[16–18]. Consequently, an EFA with maximum likelihood extraction with promax rotation was conducted with the assumption of normality of the data.

Both participant sample size (focal-proximate, n=210; diffuse-proximate, n=208) to variables (30) ratios exceeded the minimum recommended ratio for EFA of 5 to 1, with a minimum participant sample of 150[19]. Bartlett's test confirmed that an EFA was appropriate for the focal-proximate sample (χ^2[435]=8290.70, p<.001) and diffuse-proximate sample (χ^2[435]=11068.50, p<.001). A Keiser–Meyer–Olkin (KMO) test indicated there was a sufficient participant:item ratio for both the focal-proximate sample (7:1, KMO=.96) and the diffuse-proximate sample (6.93:1, KMO=.96).

Parallel analysis was used to determine the number of factors to extract, based on findings suggesting that this method (in which eigenvalues are compared to those expected from purely random data) is the most appropriate and accurate[20,21]. For the focal-proximate sample, the third eigenvalue (17.71, 3.91, 1.50) failed to exceed the third mean eigenvalue (1.79, 1.67, 1.59) calculated from 1,000 generated datasets with 210 cases and 30 variables, suggesting a two-factor solution. For the diffuse-proximate sample, the third eigenvalue (21.31, 2.81, 1.03) also failed to exceed the third mean eigenvalue (1.79, 1.67, 1.59) calculated from 1,000 generated datasets with 208 cases and 30 variables, again suggesting a two-factor solution.

A two-factor solution was therefore sought for both samples using a promax rotation, as the factors were anticipated to be correlated, with delta set to 0 (Table 1). Meaningful loadings were assessed using the criteria of 0.32 (*Poor*), 0.45 (*Fair*), 0.55 (*Good*), 0.63 (*Very good*) or 0.71 (*Excellent*)[22], with a minimum of three items loading significantly on any element to confirm it as an independent factor[23,24]. Both solutions are best described by the original two-factor model, comprising motor and cognitive factors. However, for the focal-proximate sample, one supposedly motor item ('swallowing') loaded on the cognitive factor rather than motor, despite being theoretically connected to the latter. Furthermore, among both samples, both factors were highly correlated; focal-proximate, r=.62, and diffuse-proximate, r=.73.

- Insert Table 1 here -

Confirmatory Factor Analysis

To explore the structural validity of the FIM+FAM, a series of comparisons using CFA was performed using AMOS 24 software with the second sets of randomly-assigned samples (focal-proximate, n=210; diffuse-proximate, n=207). Though evaluating acceptability of model fit against key criteria is a major focus of CFA, it is additionally useful for demonstrating the incremental value of proposed models[25]. This is important for the current consideration, which seeks not to exclude items, but to understand how best to conceptualise the relationships between the variables. Six possible models were tested for goodness-of-fit. The first was the proposed two-factor structure comprising motor and cognitive components[8], which incorporates our findings from EFA. The second structure was a three-factor model[11], comprising motor (15 items, with the 'swallowing' item excluded), psychosocial (9 items)

and communication factors (5 items). The third structure was the four-factor model[7], comprising physical (15 items, without the community mobility item), psychosocial (9 items), communication (5 items) and activities of daily living (6 items, plus community mobility) factors. The fourth proposed structure was a unidimensional model representing an underlying latent factor structure of general functioning. The fifth, sixth and seventh structures were bi-factor versions of the two-, three- and four-factor models.

To examine the goodness-of-fit of the data against key criteria, we used the following recommended statistics[26,27]: the chi-square (X^2), the comparative fit index (CFI), the non-normed fit index (NNFI) and the root mean square error of approximation (RMSEA). Additionally, we report the relative chi-square degrees of freedom (CMIN/DF). We used the following criteria to assess whether the model fit was adequate (noting the chi-square test was likely to be significant due to the large sample size[28]); (i) the relative chi-square (CMIN/DF) should be less than 3 to be acceptable, and less than 2 to be 'good', (ii) the CFI and NNFI should exceed .90 to be acceptable and exceed .95 to be 'good' and (iii) the RMSEA should not exceed .08, and should be below .06 to be a 'good' fit [27,29]. In terms of improved fit for models, we assessed improved goodness-of-fit by changes in CFI (ΔCFI) being >.01[30].

Table 2 shows goodness-of-fit statistics for the seven models. Among both the focal-proximate and diffuse-proximate samples, nearly all the goodness-of-fit statistics did not meet all the aforementioned criteria for acceptability (noting that the SRMR is unobtainable for the four-factor and corresponding bi-factor model[7], due to one factor comprising one item). There was one exception; the three-factor[11] bi-factor model analysis met the acceptability criteria for goodness-of-fit statistics, where the CFI statistic exceeded .90. In terms of improvement of fit for CFI statistics obtained compared to other models[25], as

indicated by changes in ΔCFI being >.01[30], the three-factor bi-factor model proved the better fit among both the focal-proximate and diffuse-proximate samples than the six other proposed models. The variance accounted for by the general factor in the three-factor bi-factor model was 74.7% and 80.4% for the focal-proximate and diffuse-proximate samples respectively. The variance accounted for by the motor, psychosocial and communication factors were, respectively, 6.8%, 12.0% and 6.6% for the focal-proximate sample, and 3.2%, 10.8% and 5.6% for the diffuse-proximate sample.

- Insert Table 2 here -

Discussion

The current study suggested potential validity of a more general interpretation of FIM+FAM scores. We examined FIM+FAM factor structures among patients with focal-proximate and diffuse-proximate ABI, comparing single versus multifactorial solutions, with the assumption that the former could offer greater clinical utility in some situations. The EFA suggested a two-factor solution consistent with the original scoring of the scale[9], while the CFA suggested a three-factor[11] bi-factor solution presented the best fit. However, our EFA and CFA suggest a weighting towards a single general factor. For the EFA, in both focal-proximate and diffuse-proximate brain injury patients, the loadings for some items were above 1, suggesting a high degree of multicollinearity between the items[31], and the correlations between the factors were large[32] (r >.62). For the CFA, the general factor also accounted for a high degree of variance (>74.7% across both samples), suggesting that the variance for the items was explained by the general factor. This may have implications for

conceptualisation of FIM+FAM scores; our findings suggest a higher-order structure to these items, with the general factor underpinning overall functioning and informing group factors. This finding is consistent across the two major aetiological groupings of focal-proximate and diffuse-proximate brain injury.

This evidence for a single general factor contrasts with recent findings suggesting that the FIM+FAM comprises multiple factors[8,11,33]. These differences might relate to various issues. Firstly, the current study omitted the Extended Activities of Daily Living component due to poor data quality, which might explain differences in derived structure from previous research. Secondly, the timeframe for scoring differed across studies; for example, a previous study's[8] scores were obtained within 48 hours of admission, while the current study's scores were generated within 10 working days consistent with manualised administration[9]. This provided more time for teams to assess admissions, which may have generated differences in scoring. Finally, cohorts differ between studies, which may have produced differential outcomes. Previous research has assessed factor structure specifically with traumatic brain injury[8] and stroke patients[11], while this study utilised data from an inclusive sample of patients with trauma, stroke and other acquired aetiologies; this is representative of typical cohorts assessed using the FIM+FAM.

The finding of a general factor informing group factors in a bi-factor model[12] presents a different theoretical proposition to the currently-dominant view that the FIM+FAM generates specific and independent factors (e.g. motor, psychosocial and communication) describing function post-injury. Clearly, the ability to assess specific domains in brain injury outcomes is crucial to evaluate differential progress, to generate appropriate rehabilitative goals, and to make realistic prognostic predictions[34]. However, availability of a general factor

of functioning which provides an equivalent (or better) summary of overall impairment may also be useful, as simpler models tend to be more helpful and pragmatically applicable in clinical settings[35]. An immediate target for future study would be to explore the evaluative/prognostic utility of the general versus specific conceptualisations in bi-factor FIM+FAM models – particularly given the variance in prior research in terms of time-frames, measures used, brain injury aetiologies and inclusion (or not) of the Extended Activities of Daily Living component. The general factor providing a useful model for assessment and prognosis would be theoretically and clinically important in rehabilitation.

Limitations

Distinguishing between focal-proximate and diffuse-proximate injury is important; many ABIs combine elements of both, and while we attempted classification via broad categorisations, the clinical delineation is not always clear. This may have affected the derived factor structures. In this retrospective analysis, detailed data was unavailable to classify injuries more accurately as focal/diffuse; however, future studies should consider acquiring/using this information.

It is also important to consider that including only patients with very complex injuries both limits generalisability to those with less complex injuries, and may have masked differences in functional ability which could potentially be more evident in those with less generalised/complex impairment.

The lack of good-quality Extended Activities of Daily Living data limits comparability with some past research; future studies should discriminate between minimum

scores denoting actual minimum function, versus no assessment. Additionally, pooling admission/discharge data for factor analysis risks high intercorrelation between scores. Finally, generalisability is limited when multivariate models are developed/tested at one rehabilitation unit[37]; confirmatory studies from additional sites are required.

Conclusions

This study reports the first factor analysis of FIM+FAM scores to draw a distinction between focal-proximate and diffuse-proximate brain injury, and to test bi-factor models. Our findings suggested that although independent factors can be derived from FIM+FAM item scores, there is a convergence towards a factor describing overall functioning, which additionally informs specific group factors following brain injury. This may with further study prove to be of significant clinical utility.

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Table 1

*Exploratory Factor Analysis (Maximum Likelihood Extraction with Promax Rotation) of the FIM+FAM items.**

	Focal-proximate (*n* = 210)		Diffuse-proximate (*n* = 208)	
	1	2	1	2
Eating	**0.530**	0.324	**0.719**	0.224
Swallowing	0.315	**0.461**	**0.587**	0.316
Grooming	**0.611**	0.349	**0.676**	0.313
Bathing	**0.785**	0.173	**0.760**	0.215
Dressing (upper)	**0.758**	0.191	**0.859**	0.115
Dressing (lower)	**0.891**	0.054	**0.918**	0.038
Toileting	**0.883**	0.032	**0.955**	0.008
Bladder (assist)	**0.786**	0.095	**0.841**	0.088
Bowel (assist)	**0.802**	0.116	**0.884**	0.080
Bed chair (transfer)	**1.044**	-0.121	**1.065**	-0.120
Toilet (transfer)	**1.041**	-0.129	**1.055**	-0.094
Tub/shower (transfer)	**1.007**	-0.174	**1.016**	-0.076
Car (transfer)	**0.720**	0.088	**0.824**	0.045
Locomotion (walking)	**0.961**	-0.088	**0.908**	0.013
Stairs	**0.931**	-0.148	**0.946**	-0.140
Community (mobility)	**0.558**	0.179	**0.564**	0.193
Comprehension	0.044	**0.822**	0.149	**0.772**
Expression	0.003	**0.809**	0.204	**0.736**
Reading	0.080	**0.660**	0.202	**0.673**

Writing	0.146	**0.543**	0.224	**0.581**
Speech intelligibility	0.091	**0.575**	0.303	**0.555**
Social interaction	-0.092	**0.885**	-0.035	**0.904**
Emotional status	-0.035	**0.783**	-0.066	**0.862**
Adjust to limits	-0.045	**0.891**	-0.117	**0.992**
Leisure activities	0.139	**0.690**	0.125	**0.756**
Problem solving	0.021	**0.842**	0.097	**0.771**
Memory	0.000	**0.883**	-0.096	**0.961**
Orientation	-0.155	**0.976**	-0.126	**1.017**
Concentration	-0.057	**0.898**	0.068	**0.842**
Safety	0.052	**0.782**	0.102	**0.747**

*Loadings that could be considered above 0.45 ("Fair")[36] are bolded.

Table 2

Confirmatory Factor Analysis Fit Statistics for the Different Models Proposed for FIM+FAM Scale.

	*x*2	df	*P* =<	CMIN /DF	CFI	NNFI	RMSEA
	Focal-proximate Sample (*n* = 210)						
2-factor	2544.29	404	.000	6.30	.764	.746	.159
3-factor (Nayar)	2090.74	374	.000	5.59	.803	.786	.148
4-factor (Turner-Stokes)	2356.47	400	.000	5.89	.784	.765	.153
Unidimensional	3809.62	405	.000	9.41	.624	.596	.201
2-factor (Bi)	2331.38	375	.000	6.22	.784	.749	.158
3-factor Bi (Nayar)	1198.53	345	.000	3.47	.902	.885	.109
4-factor Bi (Turner-Stokes)	1423.04	370	.000	3.84	.884	.863	.117
	Diffuse-proximate Sample (*n* = 207)						
2-factor	3006.18	404	.000	7.44	.756	.737	.177
3-factor (Nayar)	2352.97	374	.000	6.29	.807	.790	.160
4-factor (Turner-Stokes)	2600.77	400	.000	6.50	.794	.776	.163
Unidimensional	4142.10	405	.000	10.23	.650	.624	.212
2-factor (Bi)	2690.70	375	.000	7.18	.783	.748	.173
3-factor Bi (Nayar)	1481.27	345	.000	4.29	.889	.870	.126
4-factor Bi (Turner-Stokes)	1713.52	370	.000	4.63	.874	.852	.133