Assessment and rehabilitation in acquired brain injury:

The role of social and therapeutic engagement in recovery

Thesis submitted to the University of Leicester Department of Psychology, in partial fulfilment of the requirements of the Doctorate in Clinical Psychology (DClinPsy)

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Declaration

The research reported herein is my original work, and has not been submitted for any other academic award. The thesis has been checked for completion prior to submission.

Assessment and rehabilitation in acquired brain injury: The role of social and therapeutic engagement in recovery (Sarah Gunn)

Thesis Abstract

Rehabilitation outcomes following acquired brain injury are affected by a complex mix of variables, including demographics, injury characteristics, post-injury function and intensity and duration of rehabilitation. Assessing key factors and making prognostic judgements is therefore difficult. This thesis aimed to develop a greater understanding of assessment and predictive factors in rehabilitative outcomes following acquired brain injury, particularly focusing on the role of therapeutic and social engagement in rehabilitation.

Literature Review

The Functional Independence Measure and Functional Assessment Measure is used extensively in UK rehabilitation services and worldwide; however, no recent review has been conducted into its psychometric properties. The current review examined 28 quantitative studies derived from six databases, identifying excellent internal consistency, interrater reliability and criterion validity, and good responsiveness. However, ceiling effects were identified in less functionally-impaired populations, evidence for manualised subscales was unconvincing, and qualitative patient goals are not well-reflected in scoring.

Empirical Study

The research study comprised two investigations. Firstly, the roles of group and individual social engagement and behaviours of concern in acquired brain injury rehabilitation outcomes were explored. Multiple regressions identified that greater group participation predicts better physical recovery, and greater individual therapy participation predicts poorer cognitive recovery; the latter may relate to the typical slower recovery of cognitive function post-injury or to ceiling effects. Individuals exhibiting behaviours of concern showed better mean physical recovery than controls, although their longer mean length of stay in hospital may have contributed. In the second investigation, the convergent validity of the FIM+FAM Social Interaction was evaluated, identifying significant correlations with ecologically-valid markers of engagement (individual therapy and group participation).

Appendices

The appendices provide detail about the empirical study, including the ethical review, key measures used, a methodological critique, and clinical and theoretical implications.

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Word Counts

Section	**Word count***
Thesis abstract	288
Literature review	7,102
Empirical report	7,925
Non-mandatory appendices	5,994
Thesis (total)	21,309

*Totals exclude tabulated data, figures/diagrams, reference lists, contents pages and mandatory appendices, but include abstracts, footnotes and references within-text.

Table of Contents

List of Tables

List of Figures

PART ONE: LITERATURE REVIEW

The Functional Independence Measure and Functional Assessment Measure (FIM+FAM): A systematic review of psychometric properties and factor structure[1][2]

[1] In journal format (Appendix A); submitted to *Disability and Rehabilitation* 01/2019.
[2] Anonymity checklist: Appendix B.

Abstract

Purpose: To evaluate evidence for the psychometric properties and factor structure of the Functional Independence Measure and Functional Assessment Measure (FIM+FAM) in acquired brain injury rehabilitation.

Design: A systematic review of six databases was undertaken following PRISMA guidelines in October 2018, identifying 28 relevant papers. Due to methodological and sample inconsistencies between studies, meta-analysis was inappropriate.

Results: The FIM+FAM possesses excellent internal consistency, interrater reliability and good responsiveness, better for motor than cognitive/communication/psychosocial items, and better with team than individual ratings. Criterion validity was excellent, correlating appropriately with similar/dissimilar measures and clinical indicators. Ceiling effects were moderate at inpatient admission, greater in discharging samples; floor effects were only identified in children. Evidence for predictive validity and discriminatory capacity between aetiologies was limited. Factor analysis suggested that FIM+FAM total may possess equivalent utility to the less well-supported subscales. Compared with the original Functional Independence Measure, FIM+FAM psychometric properties were similar except for reduced ceiling effects and poorer interrater agreement.

Conclusions: Team-rated FIM+FAM is recommended for neurorehabilitation inpatients. Subscales, particularly Cognitive, should be used cautiously; total scores may have better utility. Collecting additional qualitative patient goals would provide a more holistic overview of progress.

Introduction

Acquired brain injury (ABI) frequently causes long-lasting physical, cognitive, emotional, social and behavioural changes, often requiring intensive, long-term rehabilitation (Mazaux & Richer, 1998; Shames et al., 2007). Accurate functional assessments enable interdisciplinary teams to quantify impairment, generate meaningful rehabilitative goals, advise on prognosis, and identify appropriate discharge placements (Balasch i Bernat et al., 2015; Cope & O'Lear, 1993; Hall et al., 1994; Hall et al., 1993; Nayar et al., 2016; Ponsford et al., 2008; Turner-Stokes, 2009). One of the most broadly-used outcome measures in complex ABI rehabilitation services worldwide is the 30-item Functional Independence Measure and Functional Assessment Measure (FIM+FAM), which assesses physical, cognitive and psychosocial function (Skinner & Turner-Stokes, 2006; Turner-Stokes et al., 1999; Turner-Stokes & Turner-Stokes, 1997). It comprises the original Functional Independence Measure (FIM), developed as a discipline-free measure of functional impairment in motor tasks and activities of daily living, and the newer Functional Assessment Measure (FAM), developed specifically to evaluate cognitive, behavioural, communication and community-based functioning post-ABI (Granger et al., 1990; Hall, 1992; Hall et al., 1993; Hall & Johnston, 1994; Keith et al., 1987; Wilson et al., 2009).

The original FIM scores 18 functional activities on a seven-point ordinal scale (1 = total assistance; 7 = total independence) (Hall et al., 1993). It possesses excellent reliability and validity (Kidd et al., 1995), good interrater agreement (Hamilton et al., 1994; Hamilton et al., 1991; Ottenbacher et al., 1996) and responsiveness (Hall et al., 1993), discriminatory capacity between severities of traumatic brain injury (TBI) (Di Scala et al., 1992) and stroke (Balasch i Bernat et al., 2015; Kwon et al., 2004), predictive utility regarding functional gain (Inouye et al., 2001) and return to work (Keyser-Marcus et al., 2002), good face validity (Dodds et al., 1993) and convergent validity with clinical predictors including injury severity, duration of inpatient stay, and post-discharge care needs (Cowen et al., 1995; Heinemann et al., 1993). However, some items are difficult to score reliably (Granger et al., 1993) and severely-impaired patients engender floor effects (Whitlock & Hamilton, 1995). The FIM also has limited sensitivity to cognitive impairment (Hall & Johnston, 1994) and community integration

(Kaplan & Corrigan, 1994), and poorer predictive value regarding cognitive recovery (Corrigan et al., 1998; Linacre et al., 1994; Willer et al., 1993). The 12 additional FAM items use the same seven-point scale (Hall, 1992); they were initially developed for US TBI patients (Hall et al., 1993; Willer et al., 1993) but later adapted for UK use with slight linguistic changes (Turner-Stokes et al., 1999) and validated for TBI, stroke and general ABI populations (Nayar et al., 2016; Turner-Stokes & Siegert, 2013). The FAM has good clinician-reported utility (Pentland et al., 1999).

In the full FIM+FAM (Appendix C), nine items assess basic self-care (e.g. continence, grooming), seven assess mobility/transfers, six assess communication, and nine assess cognitive/psychosocial functioning; together these generate total scores and Motor/Cognitive subscale scores (Turner-Stokes et al., 1999; UK FIM+FAM Users Group, 2010). Six "extended activities of daily living" (EADL) items also assess community-based tasks (e.g. shopping, financial management) (Law et al., 2009). The FIM+FAM is the key outcome measure for the UK Rehabilitation Outcomes Collaborative (Turner-Stokes et al., 2012) and validated versions are used in Europe, South America, Australasia, East Asia and the Middle East (Hadian et al., 2012; Leon-Carrion et al., 2005; Lourenco Jorge et al., 2011; Miki et al., 2016; Naghdi et al., 2016). It is a reliable, valid scale possessing excellent internal consistency, high test-retest and interrater reliability and good responsiveness (Hall et al., 2001; Law et al., 2009; Turner-Stokes et al., 1999; Turner-Stokes & Siegert, 2013; Wilson et al., 2009). It provides more information than the FIM about patient capabilities/goals (Turner-Stokes, 2002; Turner-Stokes et al., 2009) and correlates significantly with key clinical variables, including Glasgow Coma Scale scores (Hall et al., 1993).

However, the FIM+FAM is not an unqualified improvement. While it arguably increases Cognitive subscale interrater reliability over the FIM (Donaghy & Wass, 1998), raters report difficulty scoring the more abstract cognitive/psychosocial items, which reduces overall reliability (Alcott et al., 1997; Hall, 1992; McPherson et al., 1996; Turner-Stokes et al., 1999). Some studies additionally find no improvement over the FIM in validity (including predictive validity), responsiveness or reliability (Hobart et al., 2001; Linn et al., 1999; McPherson & Pentland, 1997). Additionally, while the FIM+FAM may reduce FIM ceiling effects by using more challenging items, this reduces test efficiency and interrater reliability (Hall et al., 1996, 1993; Nayar et al., 2016) and some findings still show little/no improvement over the FIM in difficulty/range (Tesio & Cantagallo, 1998; Wilson et al., 2009). Finally, rating contributions to FIM+FAM total scores are inconsistent; scores of 2-6 contribute significantly, but not extreme ratings (1/7) (Marosszcky, cited in Gurka et al., 1999).

The FIM+FAM's factor structure is also unclear. While (Hawley et al., 1999) identified a two-factor interpretation fitting the manualised Motor and Cognitive subscales (UK FIM+FAM Users Group, 2010), others identified three-factor (Nayar et al., 2016), four-factor (Hall et al., 2001) and bifactor models (Gunn et al., 2018) better fitting the data. All models retained the Motor subscale but the cognitive/social/behavioural/communication items factored out differently, possibly due to difficulties with abstractness.

Previous Reviews

Turner-Stokes and Siegert (2013) reviewed evidence regarding FIM+FAM psychometric properties and factor structure, but eleven further papers were identified for inclusion in this review. Additionally, the prior review evaluated FIM+FAM evidence for inpatient and outpatient populations, which may have complicated outcomes since people in community rehabilitation evidence different recovery patterns (Powell, 2002) and different sensitivity, specificity and ceiling effects (Seel et al., 2007). A Cochrane database search found no complete/proposed relevant reviews. A new systematic review focused purely on the FIM+FAM's use in inpatient populations is therefore clinically valuable and avoids replicating past work.

Review Aims

All FIM+FAM psychometric properties were evaluated, including:

1) Reliability and validity of the total FIM+FAM and Motor and Cognitive subscales (internal consistency, interrater/test-retest reliability, item abstractness,

responsiveness, floor/ceiling effects, discriminatory effectiveness, predictive validity, criterion validity, ecological validity).

2) Factor structure.
3) Whether the FIM+FAM offers benefits over the FIM, justifying its greater administration time.

Method

A systematic literature search was undertaken on 28/10/18 on CINAHL, Medline, PubMed, PsycINFO, Scopus and Web of Science with no date limitations and using any version of the FIM+FAM (search terms: Appendix D), generating 198 results, from which 87 duplicates and non-English language articles were removed. Only studies of inpatient samples were included, as noted above. The remaining 111 articles were imported using Mendeley. Following title/abstract screening, 56 more were excluded using the inclusion/exclusion criteria (Appendix D), leaving 55 which were read in full. Twenty-six related to FIM+FAM psychometric properties; the remainder were excluded (shortlisting process: Appendix E). Searching references of included articles identified 13 more potentially-relevant papers, which were screened using the same process. Included papers were quality-assessed using the COnsensus-based Standards for the selection of health Measurement INstruments checklist (COSMIN; Mokkink et al., 2018) (Appendix F). A data extraction tool was developed to extract review-relevant information (Appendix G). Appendix H summarises the key aims/outcomes/quality information from included articles.

Results

Of the 26 reviewed papers, seven included mixed ABI samples, four included additional neurological groups, 15 focused on specific groups and five included healthcare professionals (exclusively or combined with patients) (sample characteristics: Appendix I). Meta-analysis was inappropriate due to insufficient similarity of method/measures/samples between papers. Most studies used the US

FIM+FAM (or did not specify); six studies used the UK version and one used the Italian version.

Study Quality

Papers ranged in quality from adequate to very good on the COSMIN checklist. Eight papers received "doubtful" quality ratings for specific components of their analysis. Turner-Stokes and Siegert's (2013) paper was rated "doubtful" for their assessment of structural validity due to their sample being undersized for Mokken analysis according to COSMIN criteria. Gunn et al.'s (2018) evaluation of construct validity (discrimination between populations) was rated "doubtful" due to inadequate description of sample characteristics between groups. Hobart et al. (2001) did not report weighted kappa values and had an underpowered analysis due to small sample in their reliability analyses; Hall et al. (1993), Turner-Stokes et al. (1999) and McPherson et al. (1996) also did not report weighted kappas and were likewise rated "doubtful". Finally, Bajo et al.'s (1999) and Wilson et al.'s (2009) evaluations of responsiveness was rated "doubtful" due to limited description of subgroups. As per COSMIN guidelines, separate checklists were completed for separate dimensions of psychometric analysis, so a "doubtful" rating on one element of a paper did not affect ratings of other properties examined by the paper. Analyses with "doubtful" ratings were still included due to the limited evidence base, but caution was exercised in interpretation and weighting of findings.

There were also more universal concerns across the literature. No study reported blinding discharge or follow-up raters to earlier FIM+FAM ratings, even though therapists/researchers may consciously or unconsciously up-score patients if aware of previous ratings. Confound recording and analysis were also weak/absent for most studies, and lack of power analysis and high attrition were also frequently problematic (discussed further under Statistical Methodologies).

Finally, six papers (Foy & Somers, 2013; Grauwmeijer et al., 2012, 2014, 2017; Pietrapiana et al., 2005; Valk-Kleibeuker et al., 2014) assessed predictive validity which is not rated using the COSMIN checklist.

Structural Validity

The four studies examining structural validity were of adequate or better quality. Hawley et al. (1999) identified a two-factor structure (motor and cognitive components), reflecting the FIM+FAM manualised subscales and accounting for 83.6% of score variance. Rasch analysis showed multiple items not conforming to infit/outfit desirable criteria, but overall raw ratings were clinically-useful for characterising level of function. While the import of these findings is lessened as only exploratory, not confirmatory, factor analysis was conducted, the sample size more than met criteria for power. Alternatively, Nayar et al.'s (2016) study – rated "very good" – used both exploratory and confirmatory factor analysis and reported a three-factor UK FIM+FAM solution accounting for 69% of variance using motor, communication and psychosocial subscales (15 of 16 original Motor items were retained for the motor factor, excluding Swallowing). The divided cognitive component compared to Hawley et al. may arise from the improved level of analysis, or from Nayar et al. studying stroke patients, in whom cognitive scores may present less cohesively due to motor changes affecting communication/psychosocial items differently.

Conversely, Turner-Stokes and Siegert (2013) reported four UK FIM+FAM factors based on Mokken analysis; while the Motor subscale again remained largely-intact (this time excluding Community Mobility) and the Cognitive subscale split into psychosocial and communication factors, EADL comprised a separate factor (including Community Mobility). All subscales were strong (H>.50) with excellent internal consistency (α >.90-.97) and large responsiveness effect sizes (d>0.80, smaller for psychosocial/communication than physical/EADL), although four cross-loading items were subjectively assigned to their manualised scales. As noted above, however, the Mokken analysis was extremely underpowered so these findings are of doubtful value.

Finally, Gunn et al. (2018) conducted exploratory and confirmatory factor analysis with a mixed-ABI sample. Their findings indicated that a bifactor model, in which overall functioning provided equivalent explanatory value to three independent factors (motor, psychosocial and communication), explained 75% and 80% of UK FIM+FAM variance for focal- and diffuse-ABI samples respectively. This suggests overall

FIM+FAM scores might possess equivalent clinical utility and offer as good a fit to patient data as multidimensional models with several components. This was one of two “very good” rated analyses from the evidence base, and consequently the two-factor and bifactor outcomes are best-supported.

Overall, the Motor scale holds integrity well under factor analysis in different populations (although Nayar et al. (2016) reported slightly-different factor structures when comparing left- and right-sided ABI), except the Swallowing item which dropped from Gunn et al.’s (2018) motor factor and loaded weakly on Nayar et al.’s (2016) motor and communication factors, suggesting it may lack validity as a Motor subscale item. The remaining items cluster inconsistently, possibly due to aforementioned poor Cognitive subscale validity/reliability, difficulties conceptualising cognitive/psychosocial items, or sampling/population differences. Therefore, the manualised Motor subscale can be used with relative confidence; Cognitive subscale outcomes should however be interpreted cautiously. Total scores may be equally effective, without incurring threats to validity.

Content Validity

Content validity has been little-explored; the literature comprises only two studies with disparate methodology. Alcott et al. (1997) assessed “imageability” (ease of bringing an image to mind) of keywords based on four Cognitive and four Motor items. Motor items had significantly higher imageability (6.02-6.59) than Cognitive (2.00-3.02). However, the authors used keywords and not the items themselves, potentially impairing generalisation to FIM+FAM items and affecting the study quality rating (“adequate”). Increasing Cognitive item concreteness via additional training and enhancing item descriptions was suggested, e.g. by deconstructing abstract items like Problem Solving into domestic/interpersonal/mechanical components. This already occurs for motor skills (e.g. transfers subdivided to transfers to chair, bath, car…).

Law et al. (2009) also assessed the effect of “black-and-white” (matching criteria clearly) versus “grey” (ambiguous) vignettes on accuracy/reliability in their study rated “very good” for quality. Excellent accuracy and intrarater reliability were maintained for individuals and teams, and for interrater reliability in teams, but individual interrater reliability was only “good”, reinforcing that team scoring is preferable. Overall, ambiguity and clarity of item description appear important, but the evidence base is highly limited.

Floor and Ceiling Effects

Floor and ceiling effects, while not explicitly covered by COSMIN, are an important indicator of comprehensiveness and therefore relevant to content validity (Mokkink et al., 2010). The literature indicates that Hall et al. (1996) found that FIM+FAM ceiling effects increased between discharge (34% achieving modified/total independence) and two years post-injury (79%). Four FAM items offered high variance and precision, and two FIM items offered high precision only. However, these results were not assessed for significance or effect size. Importantly, the sample included patients capable of 3+ hours’ rehabilitation daily, which is unusual in inpatient settings; ceiling effects might therefore be milder in more severely-impaired populations.

Similarly, Wilson et al. (2009) reported substantial ceiling effects upon inpatient discharge for the UK FIM+FAM Motor (62%) and Cognitive subscales (56%). Fifty percent or more of patients reached ceiling on 13/16 Motor items and 11/14 Cognitive items, suggesting this measure may be inappropriate for assessment after inpatient rehabilitation. Linn et al. (1999) also found that 14-23% of inpatients on admission and 40-54% on discharge exhibited ceiling effects, but found minimal floor effects. Likewise, Bajo et al. (1999) identified admission ceiling effects of 76% and 79% for the self-care and mobility subscales respectively, indicating that even inpatients early in rehabilitation may reach ceiling on some FIM items – although they specifically recruited in a unit focusing on cognitive/neurobehavioural issues post-ABI, which potentially affected findings.

Hobart et al. (2001) found good FIM+FAM score variability (total: 32-204, Motor: 17-110; Cognitive: 15-98), with mean scores near the range midpoints (total: 144.8; Motor: 71.0; Cognitive: 73.8), indicating comprehensive cover of a range of levels of impairment. Similarly, McPherson and Pentland (1997) found that only 2% of participants obtained maximal independence scores on discharge from inpatient rehabilitation. McPherson et al. (1996) additionally noted that none of their 30 patients reached ceiling on every item (while noting that individual item ceiling effects are also important).

The only floor effects were identified by Austin et al. (2018) using the UK FIM+FAM with children and young people, potentially because many were too young to complete tasks independently. Unfortunately, age was not included as a covariate in analyses. No ceiling effects were found, indicating that the measure is sensitive to further functional improvement in children and young people.

Overall, ceiling effects were not identified for typical neurorehabilitation inpatients or children/young people. Floor effects were only reported in the latter. Hall et al. (1996) attributed ceiling effects to rehabilitation therapists setting goals according to FIM+FAM criteria, and discharge occurring upon completion (i.e. patients reach ceiling); this may change with current drives to reduce admission duration. For groups affected by ceiling effects, measures of subtler psychosocial/cognitive outcomes may be more appropriate (Fordyce & Roueche, 1986; Prigatano & Altman, 1990).

Internal Consistency

Excellent FIM+FAM internal consistency was found across all four studies, and the analyses were all of very good quality. Hobart et al. (2001) identified excellent internal consistency for total scores (α=.96) and Motor (.96) and Cognitive subscales (.91), and acceptable consistency on item-total correlations (>.4), mean interitem correlations (>.3) and alphas (>.8). Similarly, Turner-Stokes and Siegert (2013) found excellent alpha ratings for the total FIM+FAM (.98), motor domain (.97) and cognitive domain (.96).

Two further studies produced modified subscales using factor analysis. Hawley et al. (1999) identified excellent internal consistency (Cronbach's α) for their modified physical (.99) and cognitive subscales (.98), and for total scores (.99). Nayar et al. (2016) found slightly lower values for their UK FIM+FAM motor (.97), psychosocial (.93) and communication (.88) subscales, and for total scale (.96). While these modified subscales do not strictly compare to the manualised scales, cognitive components still showed poorer internal consistency in line with findings from the manualised scales.

Reliability

Studies of reliability were of adequate or doubftful quality, highlighting a poorer evidence base for this domain; as described in Study Quality, three of six studies did not report weighted kappa.

Interrater Reliability

McPherson et al. (1996) evaluated interrater reliability by having a medic and nurse assess 30 mixed neurorehabilitation inpatients; kappa values suggest 29 items are reliable for this population (.55-.95), but not Adjustment to Limitations (.35). There was better agreement on motor items than cognitive/psychosocial/communication items; 12 of the top 14 items (kappa ≥.75) were Motor subscale items, and the seven poorest were cognitive/behavioural/communication items (which raters reported more difficulty scoring). Generalisability is low considering only two raters/disciplines contributed, patients had ABI, spinal or other neurological conditions and power was low, but good interrater agreement was found.

Turner-Stokes et al. (1999) examined interrater reliability of the UK and US FIM+FAM by assessing individual and team accuracy when scoring vignettes. Good interrater reliability was identified in the group (US: 84%; UK: 87%) and individual conditions (US: 75%; UK: 77%), significantly higher for groups. Findings should be interpreted cautiously, since in addition to not reporting weighted kappa values, interrater accuracy was assessed using potentially-subjective "true" scores and vignette use may impair ecological validity. Small-sample kappa use is also not recommended, and the study was underpowered. Individual and group ratings were also conflated, as the same participants completed both conditions.

Law et al. (2009) also assessed UK FIM+FAM EADL interrater reliability using vignettes. Fifty vignettes (ten per item) were rated by 12 multidisciplinary healthcare professionals individually and in triads. Raters had disparate professional and FIM+FAM experience, reflecting genuine teams. EADL items had excellent team

(k_w=.96) and individual (k_w=.93) agreement with pre-decided scores by experienced raters, and good-to-excellent interrater agreement (individual, k_w=.80; team, k_w=.90). Teams had better accuracy and interrater agreement than individuals for all items except Housework; scoring accuracy (individual, k_w=.88; team, k_w=.93) and interrater agreement (individual, k_w=.68; team, k_w=.88) were weakest for Laundry.

Donaghy and Wass (1998) assessed interrater reliability between individuals, limiting generalisability of findings since administration as per the FIM+FAM manual should be by teams. However, raters assessed patients (not vignettes) and the analyses chosen allowed for differing team sizes, better representing inpatient assessment. Overall, they found good-to-excellent (.6-1.0) interrater reliability for all items except Social Interaction (<.4), and excellent (≥.75) interrater reliability for all subscales except psychosocial (.63) (in which three of the four items were among the least reliable). There was generally higher interrater reliability for Motor items than Cognitive/Psychosocial. The poorest-performing Motor item was Community Access, which includes significant cognitive elements alongside physical function.

Unlike other analyses, van Baalen et al. (2006) used weighted kappa and intraclass correlations, which are considered the best quality choices according to COSMIN. They found excellent intraclass correlation coefficients for the FIM and FAM components at inpatient discharge (FIM: .92; FAM .70) and one-year follow-up (FIM: .75; FAM: .95), concluding they are appropriate for use in the first year post-injury. Raters were inexperienced with the FIM+FAM, but agreed on its application beforehand, which potentially affected administration and therefore validity. In two final studies, Hobart et al., (2001) found unusually excellent interrater reproducibility for the FIM+FAM (total scale: .98; Motor: .98; Cognitive: .97) while Hall et al. (1993) reported much poorer interrater agreement for the overall FIM (88%) and FAM (67%) (admission ratings were worse; 55% and 81% respectively).

Drawing conclusions is difficult because studies were broadly of adequate or poorer quality, and also used either FIM+FAM experienced (Turner-Stokes et al., 1999) or inexperienced staff (Donaghy & Wass, 1998; Hall et al., 1993) or both (McPherson et al., 1996). Additionally, most studies used team ratings, which may artificially increase interrater reliability; however, it is an ecologically-valid representation of inpatient administration (Donaghy & Wass, 1998). Two studies used vignettes, not patients (Law et al., 2009; Turner-Stokes et al., 1999), which may reduce ecological validity. Despite differing methodologies and problematic analytic choices which compromised study quality, findings consistently showed overall good ratings, highest reliability for motor items, and poorer cognitive/psychosocial/communication items. Donaghy and Wass (1998) suggested assigning items to specific disciplines to improve accuracy, although this disregards evidence that team ratings are more reliable (Ottenbacher et al., 1996). Segal et al. (1993) argued that poor interrater agreement results from ill-defined items and inadequate rater understanding of criteria; e.g. Adjustment to Limitations requires judgement of "general life functioning", and multiple items require similarly subjective judgements, which affected scoring in McPherson et al.'s (1996) study.

Test-retest Reliability

Law et al. (2009) reported excellent test-retest reliability (individual: k_w=.93, group: k_w=.97) for UK FIM+FAM EADL scores taken one month apart. As for accuracy and interrater agreement, team performance was stronger, and agreement for Laundry (plus Financial Management) was poorest (k_w=.92). Dropping these items was not advocated, as ratings were still excellent.

In summary, reliability ratings were disparate and relatively inconclusive, probably due to imperfect statistical analyses and a mixture of methodologies. Studies with improved statistical methodology are needed to clarify FIM+FAM reliability.

Construct Validity

Discriminating between Patient Subgroups

Five papers examined construct validity in terms of differentiating between subgroups of patients. All papers except Gunn et al. (2018) were scored "very good" for their analysis of this domain.

The FIM+FAM appears to be of limited use in discriminating between patient subgroups. Foy and Somers (2013) reported no difference in FIM+FAM score improvement between TBI and non-TBI groups (although low power undermines the reliability of this conclusion). Similarly, Wilson et al. (2009) found that UK FIM+FAM score change pre- to post-rehabilitation did not distinguish between TBI, cerebrovascular accident and other ABI/neurodegenerative diagnoses. While Balasch i Bernat et al. (2015) identified FIM+FAM cut-offs for severe and moderate disability, only lower cut-offs were established, since no patient achieved recovery to “mild disability”. This evidence is therefore unconvincing.

Two papers explored whether factor analysis highlights differences between patient subgroups. Gunn et al. (2018) found that FIM+FAM factor structure did not differ between focal and diffuse injury types, despite prior findings that focal injury may cause greater motor impairment and diffuse injury more communication/psychosocial difficulties (Power et al., 2007); however, Gunn et al.’s analysis was rated “doubtful” using COSMIN due to providing inadequate information regarding subgroup characteristics. A further factor analysis study by Nayar et al. (2016) was rated “very good” and also reported no difference between patient subgroups, specifically that FIM+FAM scores did not differentiate between right- and left-sided stroke.

Overall, FIM+FAM outcomes appear to be of little use in differentiating outcomes/needs between patient subgroups. This may relate to categorisation of diagnoses being problematic in such studies, as highly-specific diagnoses may predict different rehabilitative outcomes, e.g. anterior circulation and lacunar strokes (Ween et al., 1996), and therefore collapsing diagnoses into categories may lose vital differences between subgroups. Additionally, many injuries cause both focal and diffuse trauma so this distinction may be unhelpful, e.g. focal trauma may generate diffuse axonal injury (Nayar et al., 2016).

Responsiveness

Six papers analysed FIM+FAM responsiveness to change over time. Quality was highly variable, ranging from “doubtful” to “very good”. Three of the analyses were rated “very good”, but the remaining four had methodological concerns which undermined their conclusions. In two of the three “very good” papers, Nayar et al.

(2016) found that the UK FIM+FAM is responsive to meaningful functional changes between admission and discharge in stroke patients ($p<.0001$), and Turner-Stokes et al. (2009) found large effect sizes for internal responsiveness (change detection over time) in rehabilitation inpatients, except for the Cognitive subscale (medium effect). The third “very good” paper assessed change sensitivity and found that of 19 measures, the FIM and FAM (assessed separately) were two of the four most sensitive to change (van Baalen et al., 2006). This offers good evidence that the FIM+FAM has good responsiveness to change.

Austin et al. (2018) found smaller effect sizes for the UK FIM+FAM (with similarly better Motor change sensitivity than Cognitive), but used a non-standardised scoring protocol and a mixture of children and young people which may have confounded the conclusions. Bajo et al. (1999), in contrast to other findings, found that only the FAM component (but not FIM scores) were responsive to change between admission and discharge; this may however be due to high self-care (76%) and mobility (79%) ceiling scores on admission, which limited potential improvement, and there was inadequate information provided regarding pre- and post-sample characteristics. Sample difficulties may therefore limit the value of conclusions from this study.

Importantly, Nayar et al. (2016) highlighted the key difference in responsiveness between psychometric properties (e.g. smallest detectable difference), and clinically-meaningful change (Husted et al., 2000; Stratford & Riddle, 2005). Wilson et al. (2009) explored both, finding significant mean admission-to-discharge change on Motor, Cognitive and total FIM+FAM scores in a mixed neurological sample, as well as clinically-meaningful effect for the Motor (0.75) and Cognitive (0.52) subscales. Overall, therefore, all evidence except for two studies with methodological flaws indicate good FIM+FAM responsiveness.

Predictive Validity

Although predictive validity is not evaluated via COSMIN, six papers have assessed the predictive value of FIM+FAM scores for various rehabilitative outcomes; this evidence is therefore reviewed here.

Foy and Somers (2013) found that admission FIM+FAM scores predicted 80% of variance in discharge scores. Regarding other key outcomes, Grauwmeijer et al. (2012, 2017) found that FAM (but not FIM) scores predicted employment probability ten years post-injury, alongside length of stay and pre-injury employment status. Earlier findings from the same cohort (Grauwmeijer et al., 2012) also showed initial FAM score of <65 was associated with 6.9 times greater risk of unemployment at three-year follow-up. However, students/homemakers were considered unemployed in both studies, potentially biasing outcomes since these choices may not reflect incapability of work. Valk-Kleibeuker et al. (2014) additionally found that FAM scores significantly negatively predicted mood outcomes up to 36 months post-TBI.

Finally, Pietrapiana et al. (2005) found that FIM+FAM compound variables did not predict traffic accidents or violations post-TBI, nor were there significant score differences between those who did and did not return to driving. However, use of idiosyncratic motor/cognitive/psychosocial compound variables (rather than manualised scales) as predictors potentially compromises study validity.

Overall FIM+FAM predictive validity appears limited, restricted to future FIM+FAM scores, mood up to three years post-ABI and employment status up to ten years post-ABI. Comparability is poor due to studies evaluating different variables/relationships. The FIM+FAM may also only have a specific range of predictive utility (scores 2-6).

Ecological Validity

Again, this domain is not evaluated via COSMIN but presents an important final aspect of FIM+FAM utilty. Turner-Stokes et al. (2009) mapped personal goals onto FIM+FAM outcome criteria, finding that the FIM+FAM (62%) enabled mapping of 15% more goals than the FIM (47%) by acquiring more information via additional items. A considerably-larger proportion of patient experiences/hopes are therefore captured via the FIM+FAM, which may justify its use over the FIM despite the lack of psychometric improvement and longer administration time (Hobart et al., 2001; Linn et al., 1999).

Discussion

Overall, studies showed that the FIM+FAM possesses excellent internal consistency, interrater reliability and good responsiveness, typically better for motor than cognitive/communication/psychosocial items, and better with team ratings than individual. It is unsurprising that physical (observable) abilities are more easily-quantified than cognitive/psychosocial skills. Criterion validity showed appropriate correlations with similar/dissimilar measures and clinical indicators. Ceiling effects were greatest in discharging samples, and moderate in inpatient admission groups; floor effects were only reported in children. Evidence was limited for predictive validity, test-retest reliability and discriminatory capacity between injury types/severities. The FIM+FAM was psychometrically-similar to the FIM, except for poorer interrater agreement and reduced ceiling effects.

Sample Characteristics

Many studies sampled highly-specific populations. Seven only recruited TBI patients (Hall et al., 1993; Hawley et al., 1999; Valk-Kleibeuker et al., 2014), some with key characteristics, e.g. non-penetrating (Grauwmeijer et al., 2014), ability to complete 3+ hours' daily rehabilitation (Hall et al., 1996), or Glasgow Coma Score ≤8 (Pietrapiana et al., 2005). Balasch i Bernat et al. (2015) restricted to ischaemic/haemorrhagic stroke without disorder of consciousness, Nayar et al. (2016) to stroke patients excluding sub-arachnoid haemorrhage, and Linn et al. (1999) to stroke causing unilateral impairment. Such homogeneous samples provide valuable condition-specific outcomes information (e.g. diffuse versus focal injury (Power et al., 2007; Ween et al., 1996), but reduce generalisability across ABI populations. For mixed ABI samples, injury type/localisation should therefore always be included in analysis, e.g. as predictors in regression.

Fourteen studies recruited dischargees from single inpatient rehabilitation units (Appendix I), potentially resulting in biased models which are not generalisable across populations (Jongbloed, 1986). Eight studies recruited from between 3-60+ units, which would be beneficial where feasible in future studies. Additionally, Balasch i Bernat et al. (2015) and Valk-Kleibeuker et al. (2014) followed up inpatients post-discharge, acquiring valuable information about cohorts in home/community environments.

While there was a broad range of mean ages, consistent with inpatient cohorts, sex was a source of bias; 16 studies reported minority female representation (19-40%) (Appendix I). Given that women may exhibit differences in rehabilitation trajectory/outcomes (Fukuda et al., 2009), this reduces generalisability of findings to females. Most ethnicities/cultures were also absent, as studies were exclusively conducted in Western countries. Consideration of important inclusion criteria appeared rare; e.g. only Alcott et al. (1997), Grauwmeijer et al. (2012), Grauwmeijer et al. (2014), and Valk-Kleibeuker et al. (2014) considered linguistic ability, which could affect communication/psychosocial outcomes. Finally, while many studies sampled systematically via consecutive admissions, some studies employed convenience (van Baalen et al., 2006) or volunteer sampling (Law et al., 2009), risking bias.

Consistency between Studies

FIM+FAM administration varied between studies. For example, Gunn et al. (2018) excluded EADL items from analysis due to poor completion; their three-factor bifactor model might otherwise have produced four factors as per Hall et al. (2001). Additionally, FIM+FAM administration was not always as-manualised; Hawley et al. (1999) assessed patients within 48 hours of admission, Linn et al. (1999) within 72, Bajo et al. (1999) within five weeks and Gunn et al. (2018) by ten working days post-admission as per manual (UK FIM+FAM Users Group, 2010). Different assessment periods may affect assessment accuracy and alter outcomes. Items may also be inadequately assessed dependent on resources, e.g. Community Access should be assessed by trained raters off-unit, which is unfeasible in many inpatient services (Linn et al., 1999). Further, while the differences between the UK and US FIM+FAM are minor, these may still generate discrepancies in findings.

Most studies used retrospective data, which introduces uncertainty regarding accuracy (e.g. injury localisation is generally retrieved from patient notes, risking error compared to direct acquisition via neuroimaging (Nayar et al., 2016)). Retrospective studies also cannot plan evidence-based data collection via freely-chosen appropriate measures (Grauwmeijer et al., 2014).

Statistical Methodologies

Parametric versus non-parametric analyses. It has been questioned whether psychological/behavioural rating scales are comparable to true interval measurement scales, and therefore whether statistical operations such as factor analysis are appropriate (Baker et al., 1966; Cohen & Cohen, 2003; Hawley et al., 1999; Wright & Masters, 1982). Rasch analysis, for instance, requires transformation of raw item ratings into scores theoretically equivalent to points on a true interval scale, and assumes performance equivalence across items – e.g. that a patient who eats independently can also climb stairs independently, which is often inaccurate and should be tested specifically rather than assumed (Lundgren-Nilsson & Tennant, 2011). Such interpretations may additionally be difficult to apply across samples (Dickson & Köhler, 1996). Conversely, Tesio and Cantagallo (1998) argued that Rasch analysis is appropriate for testing ordinal scales, as it enables independent estimations of item difficulty and participant ability. However, some have contended that parametric analyses are more fitting for large-sample ordinal data, even when normality assumptions may not hold (Tabachnick & Fidell, 2014; Turner-Stokes & Siegert, 2013), not least because they provide estimates of variance and better generalisability (Altman & Bland, 2009) (bootstrapping may offer an additional option for addressing non-normal data). Alternatively, use of non-parametric data is unaffected by skewness which may occur in high-intensity rehabilitation (high dependence) or community samples (low dependence) (Turner-Stokes & Siegert, 2013). Given the lack of consensus, prudence in interpreting conclusions based on parametric analyses is appropriate (Hawley et al., 1999).

Repeated measures. Multiple papers used repeated FIM+FAM assessments from the same patients (Appendix H), which improved power but probably created higher within-sample heterogeneity than if admission-only or discharge-only scores were used (Nayar et al., 2016). Additionally, for Gunn et al. (2018), Nayar et al. (2016)

and Turner-Stokes and Siegert (2013), who completed exploratory and confirmatory factor analysis with randomised sample subsets, the two subsamples were not fully independent (as is assumed in analysis). Rarely, studies used statistical methods which permit correlation between repeated measures without violating assumptions, e.g. Valk-Kleibeuker et al. (2014) used linear mixed effects modelling and Grauwmeijer et al. (2012, 2017) used logistic regression with generalised estimating equations.

Confounds. Statistical assumptions usually were not checked and many studies omitted potential confounds from analysis (e.g. age, injury severity, sex). Additionally, Gunn et al. (2018) identified high collinearity between FIM+FAM item scores, suggesting some overlap. The accuracy of outcomes from studies using the Motor and Cognitive subscales are also questionable, as most factor analyses have identified 3+ factors. Finally, exclusively recruiting patients with highly-complex needs may confound longitudinal studies, with statistical regression to the mean misperceived as recovery (Macciocchi et al., 1998).

Most papers did not clarify procedures for missing data or high exclusion percentages, e.g. 40% of prospective participants were excluded from Turner-Stokes and Siegert's (2013) study due to incomplete FIM+FAM data, and differences between included and excluded participants were not evaluated. Attrition rates should be reported and characteristics of dropout participants examined for sources of bias. Most studies also did not report power/sample size calculations – many were under-powered – and only Nayar et al. (2016) included corrections for multiple comparisons, leaving others at risk of Type I error.

Future Research

Despite the appeal of re-using the FIM+FAM post-discharge to maintain consistency following inpatient rehabilitation, few studies have examined FIM+FAM use in home/community settings, where physical and low-level cognitive impairments (e.g. memory, orientation) typically give way to slower progress and higher-level cognitive difficulties (e.g. executive function) (Gray et al., 1994; Kilgore, 1995; Pietrapiana et al., 2005; Powell, 2002; Powell, 1999). The FIM+FAM shows ceiling effects and poorer reliability in such cohorts, perhaps due to functional abilities presenting differently in inpatient versus home/community environments (Donaghy & Wass, 1998; Hall et al., 2001; Hall & Johnston, 1994; Wilson, 1997). Community-appropriate comparison measures should be used to evaluate FIM+FAM validity post-discharge (Gurka et al., 1999; Hall et al., 1996).

Evidence is also required regarding whether different professional disciplines complete the FIM+FAM differently, and whether level/method/quality of training affects scoring (Donaghy & Wass, 1998; McPherson et al., 1996; Ottenbacher et al., 1996). Additionally, several studies combined input from patients, relatives and/or professional carers, without analysing characteristics of information from various sources.

Multicentre studies are frequently recommended but rarely conducted, despite potential bias from single-centre trials (Jongbloed, 1986). Several studies used retrospective multicentre data, which solves this problem but reduces methodological flexibility; prospective multicentre studies would enable exploration of predetermined, freely-chosen factors.

Crucially, successful rehabilitation should not simply comprise maximising scores, but restoring the person to their “normality” (Hall et al., 1996; Hall & Johnston, 1994; Hammond et al., 2004; Willer et al., 1993). The FIM+FAM lacks a life-satisfaction or wellbeing measure to assess this (Austin et al., 2018). Additionally, individuals might be capable of performing a task independently, yet perform poorly for other reasons; performance has greater relevance for outpatient populations than dependence, so development of performance-measuring scales is needed rather than attempting to recalibrate dependence-focused inpatient measures (Tesio & Cantagallo, 1998).

Few studies have assessed children/young people, except Austin et al. (2018). Turner-Stokes and Siegert (2013) also included a minority of 15-year-old participants, although did not differentiate their findings by age. Development of valid, reliable scales for younger people is essential. Finally, development of sensitive, specific cut-offs for risks, e.g. unemployment, could help identify patients who might benefit from particular support, such as vocational rehabilitation programmes (Grauwmeijer et al., 2012, 2017, 2014).

Implications for Rehabilitation

- FIM+FAM use is recommended for neurorehabilitation inpatients, but evidence is weak for less severely-impaired populations.
- Psychometric properties are strongest for team-rated Motor subscale, weakest for individual-rated Cognitive subscale.
- Various subscales proposed from factor analysis, but full-scale scores may evaluate function equally well.
- Combining FIM+FAM with qualitative measures of patients' goals offers holistic, person-centred assessment of progress.

Conclusion

The FIM+FAM is a valid, reliable instrument for tracking inpatient progress. However, caution is required regarding Cognitive subscale use and FIM+FAM application in non-inpatient populations, where reliability/validity is reduced. It is also essential to include individuals' aspirations, which may not map onto standardised measures, to provide a holistic overview.

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PART TWO: EMPIRICAL STUDY

Social interaction and rehabilitation: A cohort study of the effects of positive engagement and behaviours of concern on acquired brain injury rehabilitation outcomes.[4]

[4] In journal format (Appendix J).

Abstract

Background: Despite behavioural and psychosocial difficulties being very common after brain injury, they are relatively little-studied as recovery predictors. Previous research has identified that social interaction predicts physical recovery and length of inpatient stay, but it is unknown which components of social interaction are important in this regard. This study therefore examined the predictive value of interaction with peers and therapists, and of behaviours of concern which might impede social interaction. Additionally, relationships between the Functional Independence Measure and Functional Assessment Measure's "Social Interaction" item and ecologically-valid variables relating to engagement were evaluated.

Method: The predictive values of engagement with individual therapy and group activities were evaluated in rehabilitation inpatients via a series of multiple regressions, controlling for the confounds of age and type of acquired brain injury. It was anticipated that greater group and therapeutic engagement would predict greater improvements. The effects of behaviours of concern were compared by Mann Whitney U tests between a group exhibiting high levels of such behaviours, and a group of controls with no such reported behaviours, with the hypothesis that greater behaviours of concern would be associated with poorer gains. Associations between Social Interaction and theoretically-related variables were assessed via correlations, which were expected to be positive.

Results: Group attendance was positively associated with physical recovery, and greater individual therapy with poorer cognitive recovery. Individuals exhibiting behaviours of concern showed better mean physical recovery than controls and a non-significantly longer length of stay, but no difference in cognitive recovery. Social Interaction convergent validity with related variables was good, showing significant correlations with individual therapy and group activity participation, and with consultant ratings of behavioural and cognitive difficulties.

Discussion/Conclusions: Group attendance may improve physical outcomes by offering opportunities to practice functional skills and strengthening exercises. Poorer cognitive recovery with greater individual therapy may relate to slower cognitive recovery post-injury, or to ceiling effects in which more functionally-capable individuals received more therapy but had less potential for gain. The greater physical recovery for those exhibiting behaviours of concern may relate to the longer length of stay and to high inpatient support. Social Interaction appeared to be an ecologically-valid assessment of social engagement for inpatient rehabilitation settings. Overall, social interaction appears an important component in the rehabilitation process, but with more work required to fully understand its role. Study limitations and future research directions are also discussed.

Introduction

Acquired brain injury (ABI) often results in complex, enduring difficulties with cognition, social reintegration and mobility/physical function (Shames et al., 2007). Identifying effective predictors of rehabilitation is vital to improve information provision for patients/relatives, generate meaningful therapeutic goals and support discharge planning. However, multiple demographic and injury-related variables contribute to the effectiveness of neurorehabilitation, as well as factors within the rehabilitation process itself, and many are inconsistently-supported or identified only within specific ABI populations; consequently, current clinical models of recovery offer poor predictive value (Barker-Collo & Feigin, 2006; Gladman et al., 1992; Kim et al., 2015; Stinear, 2010) and electrophysiological/imaging alternatives to clinical models offer little improvement (Gunn et al., 2018; Reid et al., 2010).

Demographic, functional, psychosocial and behavioural variables contribute to predictive models (Wood & Rutterford, 2006), but psychosocial and behavioural factors are less well-studied despite social/behavioural difficulties being very common post-ABI. Frequent difficulties include self-isolation, emotional lability, apathy, disinhibition and reduced social awareness/empathy (Arnould et al., 2015; Levin, 1995; Milders et al., 2003; Olver et al., 1996; Prigatano, 1992; Rees et al., 2013), potentially resulting from social cognition deficits post-injury (Milders, 2019). Suicidal and self-harming behaviour is also common (Fisher et al., 2016), as are aggressive behaviours towards others and rule-breaking, particularly for those with language impairment, potentially suggesting links with frustration (Alderman, 2003; Ryan et al., 2015). These psychosocial/behavioural changes cause difficulties in returning to work and social/familial relationships (Bodley-Scott & Riley, 2015; Brooks et al., 1987; Malia et al., 1995), affecting home and community reintegration post-discharge (Tam et al., 2015; Winkler et al., 2006). Such psychosocial/behavioural changes could also influence ability to engage in ABI rehabilitation, and consequently affect outcomes.

Degree of positive engagement may also influence recovery (Horn et al., 2015). While Gunn and Burgess (submitted: a) identified that social/therapeutic interaction significantly contributes to recovery of physical/cognitive function and length of inpatient stay post-ABI, this study did not evaluate the social interaction construct in greater detail. However, prior studies also show social and therapeutic engagement in both individual therapy and group activities to be key predictors of ABI recovery.

Individual therapy engagement is consistently linked to recovery; both discipline-specific and holistic rehabilitation are associated with cognitive, physical and psychosocial improvement (Carney et al., 1999; Cicerone et al., 2008; Cullen et al., 2007; Turner-Stokes et al., 2015) – although this may be confounded with effects of recovery over time, and one study indicated minimal effects of therapy intensity on outcomes (Zhu et al., 2007). Increased therapy intensity is usually also associated with shorter length of inpatient stay (Blackerby, 1990; Shiel et al., 2001; Spivack et al., 1992). Type and complexity of therapeutic activity may be important; better outcomes are associated with more time in complex activities (e.g. home management, advanced gait work and problem-solving) and less time in lower-level activities (e.g. bed mobility and basic speech), i.e. greater challenges are associated with better outcomes, even for those with greater impairment (Dumas et al., 2004; Horn et al., 2005, 2015; Tepas et al., 2009; Wagner et al., 2003). This is consistent with neuroplastic recovery post-ABI being stimulated by greater challenge to the nervous system (Bayona et al., 2005; Teasell et al., 2005). However, intensity of physical rehabilitation may better predict recovery than intensity of cognitive/psychological therapy (Cifu et al., 2003) and increased therapy intensity may offer diminishing returns over time (Cullen et al., 2007), so the clinical picture is complex.

Group engagement is also key to rehabilitation. Attending social, recreational and skills-building groups appears to improve social integration, reduce isolation/behaviours of concern[5] and increase socially-appropriate interpersonal behaviours (Gerber & Gargaro, 2015; Masel & DeWitt, 2010), partially by reducing boredom which is common post-ABI (Kenah et al., 2018). Group work in post-ABI offers peer interaction/support, interpersonal learning, meaningful tasks, and a sense of belonging, acceptance and shared struggle (Gerber & Gargaro, 2015; Häggström &

[5] "Behaviours of concern" is used rather than the commonly-used "challenging behaviour" or "behaviours that challenge", which imply confrontational motivations. The former hopefully implies the need/wish to support rather than blame individuals.

Lund, 2008; Hammond et al., 2015; Patterson, Fleming, & Doig, 2017; Patterson, Fleming, Doig, & Griffin, 2017; von Mensenkampff et al., 2015). Group activities confer apparent benefits to motivation, coping and mood, and are perceived by participants/healthcare professionals to benefit social, cognitive and emotional recovery (Coulter et al., 2009; De Weerdt et al., 2001; Fraas et al., 2007; Oouchida et al., 2013; Trahey, 1991; Zanca et al., 2013). Direct comparisons of group and individual therapy are limited, but groups seem to produce similar/better outcomes (Kurasik, 1967; Trahey, 1991) or provide additive value (Vestri et al., 2014), while being more cost- and resource-effective (Coulter et al., 2009; Dobrez et al., 2004; Hammond et al., 2015; Zanca et al., 2013). Despite the apparent benefits of group engagement, however, its predictive power regarding rehabilitation outcomes is little-studied (Hammond et al., 2015). Most studies have also been conducted in outpatient environments (Backhaus et al., 2010; Dahlberg et al., 2007; Lundgren & Persechino, 1986), so evaluation in inpatient settings is required.

This study therefore aimed to examine the contributions of engagement in individual therapy and group activities to rehabilitation outcomes. One of the most widely-used measures worldwide is the 30-item Functional Independence Measure and Functional Assessment Measure (FIM+FAM; Appendix C) (Skinner & Turner-Stokes, 2006; Turner-Stokes, Nyein et al., 1999; Turner-Stokes & Turner-Stokes, 1997), which was used by Gunn & Burgess (in preparation) in their study demonstrating that social engagement is a key predictor of recovery post-ABI. The relevant predictor, the Social Interaction (SI) item, evaluates social engagement in the form of appropriateness of interaction with peers/healthcare professionals, and behaviours impairing social engagement such as withdrawal, disinhibition, sexual inappropriateness and physical/verbal aggression (UK FIM+FAM Users Group, 2010). While SI significantly/positively predicted Total FIM+FAM recovery, Motor/Cognitive subscale scores, and length of stay in Gunn and Burgess' study, SI is difficult to score (as acknowledged in the manual). Its reliability/validity is problematic due to its abstractness, as for many Cognitive subscale items (Alcott et al., 1997; Hall, 1992; Hall et al., 1993; McPherson et al., 1996; Turner-Stokes et al., 1999), and SI also exhibits poor interrater reliability where most FIM+FAM items are good-to-excellent (Donaghy

& Wass, 1998). This has been attributed to poor administrator understanding of criteria or unclear manualised guidance (Segal et al., 1993). It is therefore of additional interest to examine convergent validity between SI and the 'real-world' variables it purportedly evaluates (engagement with therapists/peers and cognitive/behavioural/emotional difficulties).

Three sets of analyses were therefore conducted (chronology: Appendix K). Firstly, the degree to which FIM+FAM SI scores correlated with markers of engagement (i.e. examining convergent validity), hypothesising that group activity and individual therapy attendance would positively correlate with SI, and that variables detracting from social interaction (cognitive/behaviour/emotional difficulties) would negatively correlate with SI. Secondly, the contributions of group activity and individual therapy to ABI rehabilitation outcomes (Motor/Cognitive/Total FIM+FAM scores, and length of stay) were examined, hypothesising that greater engagement would be associated with improved outcomes. Finally, the relevance of behaviours of concern (e.g. withdrawal, disinhibition and aggression, as per SI guidelines) to these same outcomes was evaluated, anticipating an inverse relationship.

Method

Methods for the three analyses are presented separately for clarity.

Contributors to FIM+FAM Social Interaction

Design/materials. In this cohort-design study of UK intensive rehabilitation unit inpatients, relationships between FIM+FAM admission SI score and theoretically-related variables were examined. SI scoring evaluates individuals' ability to behave as "considered socially appropriate for the environment" (UK FIM+FAM Users Group, 2010, p.60), including interacting appropriately with other patients and staff, participating in social/therapeutic activities, and level of assistance needed to manage inappropriate behaviours (e.g. aggressive, disinhibited or sexually-inappropriate language or behaviour, and withdrawn/self-isolating behaviour). Therefore, potential correlates of SI included group activity attendance, individual therapy engagement, and behavioural/cognitive/emotional difficulties. For epistemology, see Appendix L.

Inpatients were assessed using the FIM+FAM on admission, providing the SI score. The FIM+FAM is the key UK Rehabilitation Outcomes Collaborative measure, used throughout UK rehabilitation services (Turner-Stokes et al., 2012). It is a broad-spectrum, reliable, validated measure of post-ABI impairment with high internal consistency, evaluating functional, cognitive and psychosocial outcomes across a 30-item interdisciplinary team assessment (Gunn & Burgess, submitted; Macciocchi et al., 1998; Mizrahi et al., 2012; Nakayama et al., 1994; Nayar et al., 2016; Turner-Stokes & Siegert, 2013; Weimar et al., 2002). It possesses excellent internal consistency, interrater reliability and criterion validity, and good responsiveness across studies (Hall et al., 2001; Law et al., 2009; Turner-Stokes et al., 1999; Turner-Stokes & Siegert, 2013; Wilson et al., 2009; for summary, see Gunn & Burgess, submitted).

The FIM+FAM generates Total scores and Cognitive and Motor subscales (Turner-Stokes et al., 1999; UK FIM+FAM Users Group, 2010), which have good interrater reliability, Motor more than Cognitive (Donaghy & Wass, 1998; McPherson et al., 1996; van Baalen et al., 2006). The Motor subscale comprises items 1-16, covering self-care, bladder/bowel management and locomotion, and the Cognitive items 17-30 cover communication, cognitive and psychosocial function. FIM+FAM items, including SI (part of the Cognitive subscale), are scored between 1-7, except item 14.2 (wheelchair locomotion), which is scored between 0-6 (0 indicates mobilisation exclusively by walking); lower scores indicate greater dependence and support needs.

Hours of individual therapy and group activity data per individual were recorded fortnightly by therapists; this was averaged to a weekly statistic over the period of admission to avoid the confound of those admitted for longer having higher hours. Individual therapy included input from physiotherapists, occupational therapists, clinical psychologists, speech and language therapists, and medical staff – a measure of interaction with the interdisciplinary team. Group attendance involved attending on-site skills-based and recreational group activities such as gardening, dancing, physiotherapy exercises and building communication skills, which is typical of inpatient rehabilitation environments (Beaulieu et al., 2015). This provided a measure of engagement with peers.

Degree of behavioural/cognitive/emotional difficulties on admission were scored by patients' allocated consultants using the Patient Categorisation Tool (PCAT; Appendix M; UK Rehabilitation Outcomes Collaborative, 2012), an ordinal measure of rehabilitation needs covering 16 categories of physical, medical, cognitive and psychosocial patient complexity rated 1-3 (3 being most complex), and total scores ranging from 17-50. The PCAT is routinely used for patient complexity monitoring in ABI rehabilitation services UK-wide, but is little-researched. One recent study (Turner-Stokes et al., 2019) shows good full-scale internal reliability (α=.88) and reasonable sensitivity (76%) and specificity (75%). The three pertinent items for this study (Cognitive, Behavioural and Mood/Emotion) loaded significantly on a "cognitive/psychosocial" factor (α=.83) without cross-loading on the "motor" factor (α=.84) upon principal components analysis, in line with expectations, although an alternative analysis identified three components which casts uncertainty on this interpretation (Siegert et al., 2018). An inverse relationship with the FIM+FAM was also found (r_s=-.56) by Turner-Stokes et al., as expected since higher PCAT scores indicate greater complexity. While promising, this comprises limited evidence, and so examining the PCAT's relationship to a validated FIM+FAM item was a valuable additional output from this study. Appendix N contains further FIM+FAM/PCAT details.

Procedure. The FIM+FAM was completed for each patient approximately two weeks post-admission by their therapeutic team at the weekly interdisciplinary team meeting, according to the standardised administration protocol (UK FIM+FAM Users Group, 2010). Where team members disagreed regarding an item score, or where a patient's abilities fluctuated, the lower of the suggested scores was chosen. Items which were inapplicable to an individual (e.g. the "comprehension" item for a patient with a disorder of consciousness) were scored 1. PCAT ratings were completed by the patient's medical consultant by two weeks post-admission, describing any initial cognitive/emotional/behavioural difficulties. All information was recorded on the unit database.

Correlational analyses were conducted between admission FIM+FAM SI score and weekly mean group attendance/individual therapy, and PCAT-rated behavioural, cognitive and emotional difficulties. Bonferroni adjustments were not used, on the grounds that they are not required for a small number of planned analyses with specified hypotheses (Armstrong, 2014); the significance level for analysis was therefore set at 0.05.

Participants. All inpatients from database setup (August 2008) to data anonymisation (October 2018) with a completed admission and discharge FIM+FAM were included. This included individuals discharged due to illness/death. Exclusion criteria comprised current inpatients (with incomplete rehabilitation trajectories) and those discharged within a week (n=3, due to either not requiring inpatient rehabilitation, or being too unwell to benefit). Additionally, those with prior brain injury were excluded since this can complicate outcomes (Macciocchi et al., 1998). Some patients were temporarily discharged to acute care with serious illness; in these cases, FIM+FAMs were completed on discharge, readmission, and final discharge. For analysis, the initial admission and final discharge scores were used, summarising the overall recovery trajectory.

From the initial sample of 693, data from 145 participants were removed due incomplete data (particularly from earlier years, when group engagement and individual therapy hours were rarely recorded). Seventy-nine more were excluded because they had a non-ABI diagnosis, e.g. peripheral neurological conditions, pain syndromes, progressive conditions and non-brain trauma. Data from 469 participants were retained (demographic data: Table 1). G*Power power analysis indicated that 134 participants are required for two-tailed correlational analysis (assuming a medium effect size as prior research is lacking; alpha 0.05, power 0.95), so this requirement was met (Erdfelder et al., 1996).

Engagement Predictors of Recovery

Design/materials. The predictive value of group/individual engagement regarding cognitive/motor/overall recovery and length of stay was evaluated. As noted, the FIM+FAM was completed on admission and discharge for all inpatients, providing Cognitive, Motor and Total change scores via subtraction (change scores directly reflect improvement unaffected by baseline, unlike discharge scores). The Extended Activities of Daily Living bolt-on component of the FIM+FAM was excluded due to inconsistent completion and little research into its psychometric properties, rendering it an unknown quantity (Gunn & Burgess, submitted). Subscales were included as totals may conceal differential progress between domains (Ponsford et al., 2008), although since factor analyses have questioned the manualised subscales' validity and bifactor modelling indicates that Total scores best fit FIM+FAM outcome data, Total scores were included too (Gunn et al., 2018; Hall et al., 2001; Hawley et al., 1999; Nayar et al., 2016). Using individual items would be inappropriate, as 30-predictor models would drastically reduce power. Clinician assessment was chosen due to self-report being potentially affected by impaired insight or memory, which are common post-ABI (Gasquoine, 2016; Ownsworth & Clare, 2006), and relative-report being compromised by family typically having little contact with inpatients compared to clinicians (Milders et al., 2003). Length of stay comprised a fourth outcome measure, reflecting secondary difficulties in rehabilitation such as impediments to discharge, e.g. due to risk associated with behaviours of concern.

Predictive values of mean weekly individual therapy/group activity were assessed via multiple regressions. SI score was included as a predictor to determine whether individual therapy/group activity provided additive predictive value beyond SI, which was known to predict recovery (Gunn & Burgess, submitted). Age of ABI and ABI aetiology were included (Tables 1/2), as both independently predict recovery and could confound effects of group/individual engagement recovery (age: Balestreri et al., 2004; Dawson & Chipman, 1995; Gray & Burnham, 2000; Horn et al., 2015; Lehmann et al., 1975; Macciocchi et al., 1998; Nakayama et al., 1994; Ponsford et al., 1995; Rothweiler et al., 1998; Wood & Rutterford, 2006; aetiology: Dikmen et al., 1995;

Hankey et al., 2007; Hoofien et al., 2002; Lehmann et al., 1975; Macciocchi et al., 1998). Age and aetiology have also been found associated with psychosocial wellbeing, so including them to check non-collinearity with sociobehavioural variables is important (Bowman, 1996; Kendall & Terry, 1996; Tate & Broe, 1999). Several potential predictors were excluded (Appendix O) to avoid stringent Bonferroni corrections for large numbers of predictors, as testing multiple variables without set hypotheses carries a recommendation for Bonferroni corrections (Armstrong, 2014).

Table 1. Variable summary statistics for engagement cohort data

(* denotes values outside acceptable ranges)

Category	**Variable**	**Mean**	**Standard deviation**	**Skewness**	**Kurtosis**
Demographics and length of stay	Age of injury (years)	47.58	15.40	-0.40	-0.69
	Length of inpatient stay (days)	147.92	103.11	1.47	4.84*
	Sex female *(categorical)*	37.2%	N/A	-0.53	-1.73
	Diagnosis *(categorical)*	N/A	N/A	0.63	-0.72
Functional Independence Measure and Functional Assessment Measure	Motor score (admission) *(range 13-91)*	39.96	29.28	1.04	-0.29
	Motor score (discharge) *(range 13-91)*	61.13	37.10	0.06	-1.65
	Cognitive score (admission) *(range 3-35)*	37.90	22.92	0.61	-0.80
	Social Interaction (admission) *(range 1-7)*	3.37	2.40	0.38	-1.52
	Cognitive score (discharge) *(range 3-35)*	56.26	28.03	-0.23	-1.37
	Social Interaction (admission) *(range 1-7)*	4.44	2.35	-0.36	-1.48
	Total score (admission) *(range 30-210)*	77.86	47.31	0.70	-0.65
	Total score (discharge) *(range 30-210)*	117.39	61.61	-0.10	-1.46
Social variables	Individual therapy (weekly mean hours)	3.09	2.89	0.98	-0.46
	Group therapy (weekly mean hours)	0.41	0.10	3.93*	20.35*
Patient Categorisation Tool	Emotion rating	1.93	0.76	0.13	-1.26
	Behaviour rating	1.60	0.69	0.72	-0.66
	Cognition rating	2.54	0.66	-1.11	0.04

Table 2. Acquired brain injury diagnoses and frequency counts showing mean changes in total, Cognitive and Motor FIM+FAM scores, and length of stay, by category.

Brain injury aetiology	Frequency (percentage)	Mean Motor subscale change (standard deviation)	Mean Cognitive subscale change (standard deviation)	Mean overall change (standard deviation)	Length of stay - days (standard deviation)
Trauma	175 (37.2%)	22.83 (25.28)	19.43 (19.13)	42.26 (39.73)	134.90 (104.25)
Stroke (infarct)	56 (11.9%)	21.57 (19.58)	23.32 (14.90)	44.89 (25.19)	168.93 (95.86)
Stroke (haemorrhage)	70 (14.9%)	25.44 (22.08)	20.46 (17.79)	45.90 (36.14)	156.97 (94.46)
Stroke (sub-arachnoid)	62 (13.2%)	20.94 (23.79)	17.87 (18.05)	38.81 (37.33)	150.18 (92.48)
Anoxia	58 (12.3%)	11.52 (19.44)	10.55 (14.06)	22.10 (30.43)	156.98 (122.92)
Inflammatory condition	18 (3.8%)	17.89 (19.59)	15.39 (14.70)	33.28 (30.39)	128.39 (56.27)
Tumour	13 (2.8%)	19.69 (25.59)	14.31 (19.74)	34.00 (40.90)	172.31 (159.62)
Not recorded	18 (3.8%)	23.41 (28.40)	17.12 (18.06)	40.53 (42.35)	138.47 (93.22)

Procedure. Admission FIM+FAMs were completed as described above. Discharge FIM+FAMs were completed at the first team meeting post-discharge. Group/individual engagement data were acquired as described. Demographic and injury-related data were collated from medical records; diagnoses were categorised as per national guidelines (Table 2), and had been recorded on the database accordingly.

The effects of individual therapy, group participation and SI (controlling for age and aetiology) on Cognitive/Motor/Total change and length of stay during rehabilitation were assessed via four multiple regressions. Again, Bonferroni corrections were not used as they are not recommended for a small number of planned comparisons (Armstrong, 2014), so the significance level was set at 0.05.

For cohort studies of predictors of rehabilitation effectiveness, (Macciocchi et al., 1998) recommends controlling for effects of heterogeneous aetiologies, varying injury severity, and previous ABI (which can complicate recovery). Therefore, diagnosis was included as a predictor in regression, and those with prior ABI or not meeting criteria for NHS Level 1 rehabilitation (which carries a prerequisite complexity level) (NHS England, 2013) were excluded. The latter provides a control on injury severity, as only patients with highly-complex injury were admitted to the unit (and therefore study).

Participants. Participants were the same group as the SI convergent validity analysis (n=469). For appropriate power, Green (1991) recommends n>50+8m (m: number of predictors) to assess model fit (this analysis: n>50+(8*5)>90), n>104+m to test individual predictors (this analysis: n>104+5>109) and the larger of the two if evaluating both. The analyses were therefore adequately-powered (Wilson VanVoorhis & Morgan, 2007).

Behaviours of Concern as Predictors of Recovery

Design/measures. To analyse effects of behaviours which might impede rehabilitation, behavioural tracking information collected for risk management was collated. This detailed behaviours of concern recorded during the inpatient stay for those identified as risky to self or others (a subset of n=52 from the larger sample), using recording forms individualised for each person, which produced disparate data. Reported behaviours included verbal/physical aggression towards others (n=30), self-risking or self-neglectful behaviour (e.g. declining personal care/medical input, attempting to stand/walk when unsafe, self-harming or self-isolating; n=50), behaviour apparently relating to low mood (e.g. crying, talking about wanting to die; n=28) and disinhibited behaviours (e.g. sexual comments, inappropriately touching others; n=4).

There were insufficient participants to use multiple regression for analysis of the relationship between behaviours of concern and rehabilitation outcomes (minimum required: 106) (Green, 1991). Since all but one patient exhibited ≥2 categories of behaviour, it was also inappropriate to analyse the effects of behaviour types. Therefore, outcomes for those with behaviours of concern were compared against matched controls with no recorded behaviours. The control group was created by pairing each of the original 52 patients with another patient matched on age (closest within five years), sex and aetiology, with a PCAT Behaviour score of 1 (“no significant behavioural issues”). This does not guarantee no behaviours of concern were exhibited, but reduces the likelihood as much as possible. Where multiple potential controls met these criteria, selection was via online random number generator (www.random.org). For summary data, see Table 3.

Procedure. Behaviours of concern were recorded on individuals’ charts, and added to a database by team Assistant Psychologists. These data were anonymised for analysis. Demographic and aetiological data, FIM+FAM change scores and length of stay data were acquired as previously described. Mann-Whitney U tests (due to non-normal data; see Results) were used to compare between Motor, Cognitive, total FIM+FAM and length of stay outcomes between the behaviours of concern and control groups. As above, Bonferroni corrections are not recommended for these analyses so the significance level was set at 0.05 (Armstrong, 2014).

Participants. G*Power power analysis (Erdfelder et al., 1996) indicated that a Mann-Whitney U test for a presumed medium effect (d=.05 as no prior data are available; alpha .05; power .80; two tails) requires 134 participants with equal allocation between groups (Buchner et al., 1997). The 104 participants (52 controls, 52 with behaviours of concern) mean the analyses are slightly underpowered, which was borne in mind during interpretation of findings.

Ethics

The University of Leicester Ethics Sub-Committee for Psychology (Appendix P) and South Warwickshire NHS Clinical Audit and Effectiveness Department (Appendix

Q) provided approval. Data were routinely collected for progress/risk monitoring with the agreement that they could be used for future research, and were fully anonymised with only outcome data provided (no identifiers). Separate consent was not required for these retrospective uses of data (study development/ethics process: Appendix R).

Table 3. Statistics for behaviours-of-concern and control groups.

(* denotes values outside acceptable ranges)

Outcome variable	Group	Mean	Standard deviation	Median	Skewness	Kurtosis	Mean rank	Sum of ranks	Shapiro-Wilk (significance – p)	Mann-Whitney U (significance – p)
Motor admission	Behaviours of concern	39.50	25.27	31.00	0.80	-0.52	56.21	2923.00	0.85 (<.001)	1159.00 (.198)
	Controls	36.44	29.55	19.00	1.35	0.43	48.79	2537.00	0.72 (<.001)	
Cognitive admission	Behaviours of concern	30.94	15.07	30.00	0.54	-0.71	51.37	2671.00	0.91 (.001)	1293.00 (.698)
	Controls	38.29	26.79	26.50	0.71	-0.91	53.63	2789.00	0.83 (<.001)	
Total admission	Behaviours of concern	70.44	37.92	61.50	0.57	-0.98	54.10	2813.00	0.89 (<.001)	1269.00 (.586)
	Controls	74.73	53.64	51.50	1.03	-0.17	50.90	2647.00	0.81 (<.001)	
Motor change	Behaviours of concern	26.71	22.14	27.00	0.40	-0.13	61.44	3195.00	0.97 (.16)	887.00 (.002)
	Controls	15.98	23.75	4.50	1.57	1.49	43.56	2265.00	0.76 (<.001)	
Cognitive change	Behaviours of concern	21.88	17.48	19.00	0.46	-0.26	58.97	3066.50	0.97 (.30)	1015.50 (.028)
	Controls	14.88	20.42	8.00	0.95	0.23	46.03	2393.50	0.87 (<.001)	
Total change	Behaviours of concern	48.60	35.50	49.00	0.41	0.30	61.60	3203.00	0.98 (.34)	879.00 (.002)
	Controls	30.87	40.40	15.50	1.41	1.39	43.40	2257.00	0.82 (<.001)	
Length of stay (days)	Behaviours of concern	164.81	100.49	148.00	0.77	0.42	54.22	2819.50	0.95 (.042)	1262.50 (.561)
	Controls	156.29	114.00	154.50	0.92	1.09	50.78	2640.50	0.92 (.002)	
Individual therapy (weekly mean)	Behaviours of concern	3.55	2.80	3.03	0.32	-1.47	56.99	2963.50	0.88 (<.001)	1118.50 (.129)
	Controls	2.69	2.74	1.26	1.26	0.61	48.01	2496.50	0.81 (<.001)	
Group activities (weekly mean)	Behaviours of concern	0.06	0.14	0.00	4.62*	26.35*	55.76	2899.50	0.46 (<.001)	1182.50 (.202)
	Controls	0.02	0.04	0.00	2.66*	6.85*	49.24	2560.50	0.55 (<.001)	

Results

Social Interaction

Positive correlations were expected between SI and weekly mean participation in individual therapy/group activities and on-admission PCAT behaviour/cognition/emotion ratings. Pearson product-moment correlations were conducted to explore these relationships (n=469). The data were within acceptable ranges for normal univariate distribution in terms of skewness/kurtosis (i.e. not falling outside ±2, the recommended limit (Field, 2009; George & Mallery, 2010); Table 1)) except for group activity mean time; therefore, for the SI/group activities correlation, a non-parametric Spearman rank-order correlation was conducted, as this is a readily-available equivalent to parametric correlational analysis.

There was a significant positive correlation between weekly mean individual therapy and SI (r=.14, p=.003) and weekly mean group engagement and SI (r_s=.121, p=.009). A significant negative correlation was found between PCAT behaviour ratings and SI (r=-.13, p=.005), PCAT cognition and SI (r=-.39, p<.001) but while PCAT emotion rating trended towards a negative correlation, this was non-significant (r=-.09, p=.061) (Table 4).

Table 4. Correlations between Social Interaction and associated variables.

Variable assessed against Social Interaction	Pearson correlation (r)	Significance (p)	Bootstrap 95% confidence interval	
			Lower	**Higher**
Individual therapy (weekly mean)	.14	.003	0.5	.22
Group activities (weekly mean)	.12	.009	.04	.21
Consultant behaviour rating (Patient Categorisation Tool)	-.13	.005	-.22	-.05
Consultant emotion rating (Patient Categorisation Tool)	-.09	.061	-.18	.00
Consultant cognition rating (Patient Categorisation Tool)	-.39	<.001	-.47	-.31

Engagement Predictors of Recovery

Values for length of hospital stay and weekly mean group activities fell outside the acceptable ranges (Table 1); multiple regression with bootstrapping based on 1000 samples was therefore used to check confidence intervals and significance values without relying on assumptions of normality/homoscedasticity. The regression models were used to evaluate predictors of Motor/Cognitive/Total FIM+FAM change scores and length of stay. Standard analyses with bootstrapping were selected in this case as there is no direct non-parametric equivalent of multiple regression.

Motor. Single-step exploratory regression was used to examine effects of weekly mean individual therapy/group activity and SI on Motor subscale change, controlling for age of injury and aetiology (no prior research indicated that any variables should be prioritised via hierarchical regression). The final model including all five variables explained 12.4% of Motor subscale change variance. The Durbin-Watson statistic (1.88) validated the assumption of independent errors (i.e. autocorrelation between residuals was acceptably low), and the variance inflation factors and tolerance statistics showed acceptable multicollinearity and lack of intercorrelation (<10 and >0.1 respectively; O'brien, 2007) (Table 5). A P-P plot (Figure 1) indicated approximately-normal residual distribution. Analysis of variance (ANOVA) demonstrated the final model predicted Motor score change significantly better than the mean ($F(5,445)=12.65$, $p<.001$, $r2=0.124$).

Variables significantly contributing were age of injury ($t(445)=-3.40$, $p=.001$), SI ($t(445)=6.30$, $p<.001$), individual therapy (t(445=-2.33, $p=.020$) and weekly mean group attendance ($t(445)=2.82$, $p=.005$). Standardised beta values indicated that SI had the largest impact on the model ($\beta=.28$), followed by age of injury ($\beta=-.16$), then group attendance ($\beta=.13$), and finally individual therapy ($\beta=-.11$). SI had a positive relationship with Motor change ($b=2.74$; bootstrap 95% confidence interval 1.99-3.62); i.e. higher SI admission score was associated with greater Motor gains during rehabilitation. Age of injury had a negative relationship with Motor change ($b=-.24$; bootstrap 95% confidence interval -0.38--0.10); i.e. younger patients made greater physical recovery. Weekly mean group attendance had a positive relationship with Motor change ($b=30.54$; bootstrap 95% confidence interval 13.02-58.56), i.e. patients who attended more groups evidenced greater physical recovery, while weekly mean individual therapy had a negative relationship with Motor change (b=-0.89; bootstrap 95% confidence interval -1.69--0.18).

Table 5. Motor subscale score change statistics from multiple regression.

Variable	Unstandardised B	Standard error	Standardised beta	t	Significance (p)	Collinearity statistics		Bootstrap 95% confidence interval	
						Tolerance	Variance inflation factor	Lower	Upper
Age of onset	-0.24	0.07	-0.16	-3.40	.001	0.93	1.07	-0.38	-0.10
Diagnosis	-0.69	0.61	-0.05	-1.13	.258	0.93	1.07	-1.83	0.45
Social Interaction (admission)	2.74	0.44	0.28	6.30	<.001	0.97	1.03	1.99	3.62
Individual therapy (weekly mean)	-0.89	0.38	-0.11	-2.33	.020	0.86	1.16	-1.69	-0.18
Group attendance (weekly mean)	30.54	10.85	0.13	2.82	.005	0.88	1.14	13.02	58.56

Cognitive. Single-step exploratory regression was used to examine effects of weekly mean individual therapy/group attendance and SI on Cognitive subscale change, controlling for the same variables. The final model including all five variables explained 5.9% of variance in Cognitive subscale score change. The Durbin-Watson statistic (1.99), variance inflation factors and tolerance statistics were within acceptable limits (Table 6). A P-P plot (Figure 2) indicated approximately-normal residual distribution. ANOVA demonstrated that the final model predicted Cognitive score change significantly better than the mean ($F(5,445)=5.62$, $p<.001$, $r^2=0.059$).

Variables significantly contributing were aetiology ($t(445)=-2.78$, $p=.006$) and weekly mean individual therapy ($t(445)=-3.99$, $p<.001$). Standardised beta values indicated individual therapy had the largest impact ($\beta = -.20$), followed by aetiology ($\beta = -.13$). Individual therapy had a negative relationship with Cognitive change ($b=-1.21$; bootstrap 95% confidence interval -1.82--0.65); i.e. more therapy was associated with poorer cognitive gains during inpatient rehabilitation. For aetiology, values were dummies for analysis so one-way ANOVA was used to assess effects of injury type on cognitive recovery ($F(6,445)=3.14$, $p=.005$), $\eta_p^2= 0.04$). Skewness and kurtosis were within normal ranges (n=452; 17 patients were excluded from the original 469 as no injury type was recorded). Post-hoc Bonferroni pairwise comparisons showed significant differences between traumatic and anoxic ABI (mean difference=8.88; p=.019; bootstrap 95% confidence interval=4.01-13.11), between infarct stroke and anoxia (mean difference=12.77; p=.003; bootstrap 95% confidence interval=7.08-18.08), and between haemorrhagic stroke and anoxia (mean difference=9.91; p=.033; bootstrap 95% confidence interval=3.99-15.45) with anoxic patients making poorer improvement in all cases (Table 2).

Table 6. Cognitive subscale score change statistics from multiple regression.

Variable	Unstandardised B	Standard error	Standardised beta	t	Significance (p)	Collinearity statistics		Bootstrap 95% confidence interval	
						Tolerance	Variance inflation factor	Lower	Upper
Age of onset	-0.09	0.06	-0.08	-1.58	.114	0.93	1.07	-0.19	0.02
Diagnosis	-1.35	0.48	-0.13	-2.78	.006	0.93	1.07	-2.25	-0.43
Social Interaction (admission)	0.44	0.35	0.06	1.27	.204	0.97	1.03	-0.21	1.06
Individual therapy (weekly mean)	-1.21	0.30	-0.20	-3.99	<.001	0.86	1.16	-1.82	-0.65
Group attendance (weekly mean)	2.67	8.62	0.02	0.31	.757	0.88	1.14	-9.36	20.43

Total. Single-step exploratory regression was used to examine effects of weekly mean individual therapy/group attendance and SI on Total FIM+FAM change, controlling for the same confounds. The final model including all five variables explained 9.3% of variance in Total change. The Durbin-Watson statistic (1.93), variance inflation factors and tolerance statistics were within acceptable limits (Table 7). A P-P plot (Figure 3) indicated approximately-normal residual distribution. ANOVA demonstrated the final model predicted total score change significantly better than the mean ($F(5,445)=9.15$, $p<.001$, $r^2 = 0.093$).

Variables significantly contributing were SI ($t(445)=4.58$, $p<.001$), age of injury ($t(445)=-2.92$, $p=.004$), weekly mean individual therapy ($t(445)=-3.45$, $p=.001$) and diagnosis ($t(445)=-2.10$, $p=.037$). Standardised beta values indicated SI had the largest impact (β=.21), followed by individual therapy (β=-.17), then age of injury (β=-.14) and finally diagnosis (β=-.10). SI had a positive relationship with Total change (b=3.18; bootstrap 95% confidence interval 1.92-4.45); i.e. higher SI admission score was associated with greater overall gains during inpatient rehabilitation. Age of injury had a negative relationship with overall change (b=-0.33; bootstrap 95% confidence interval -0.55--0.09), i.e. younger patients made greater Total gains. Individual therapy had a negative relationship with overall change (b=-2.11; bootstrap 95% confidence interval –(-3.42--0.98); i.e. more individual therapy was associated with smaller Total gains. The latter was hypothesised to relate to those with higher need receiving more individual therapy, but a correlation between Total admission FIM+FAM score and weekly mean individual therapy was positive (r=.171, p<.001), indicating that more functionally capable individuals received more therapy.

For aetiology, as previously, values were dummies for analysis so one-way ANOVA was used to assess effects of injury type on overall recovery ($F(6,445)=3.18$, $p=.005$), η_p^2= 0.04). Skewness and kurtosis were within normal ranges (n=452; 17 patients were excluded from the original 469 as no injury type was recorded). Post-hoc Bonferroni pairwise comparisons showed significant differences between traumatic and anoxic ABI (mean difference=20.19; p=.005; bootstrap 95% confidence interval=3.58-36.81), between infarct stroke and anoxia (mean difference=22,82; p=.016; bootstrap 95% confidence interval=2.28-

43.37), and between haemorrhagic stroke and anoxia (mean difference=23.83; p=.004; bootstrap 95% confidence interval=4.36-43.31) with anoxic patients making poorer improvement in all cases (Table 2).

Table 7. Total FIM+FAM score change statistics from multiple regression.

Variable	Unstandardised B	Standard error	Standardised beta	t	Significance (p)	Collinearity statistics		Bootstrap 95% confidence interval	
						Tolerance	Variance inflation factor	Lower	Upper
Age of onset	-0.33	0.11	-0.14	-2.92	.004	0.93	1.07	-0.55	-0.89
Diagnosis	-2.04	0.97	-0.10	-2.10	.037	0.93	1.07	-4.01	-0.13
Social Interaction (admission)	3.18	0.69	0.21	4.58	<.001	0.97	1.03	1.92	4.45
Individual therapy (weekly mean)	-2.11	0.61	-0.17	-3.45	.001	0.86	1.16	-3.42	-0.98
Group attendance (weekly mean)	33.21	17.30	0.09	1.92	.055	0.88	1.14	6.18	78.83

Length of stay. Single-step exploratory regression was used to examine effects of weekly mean individual therapy/group attendance and SI on length of stay, controlling for the same confounds. The final model including all five variables explained 24.4% of variance in length of stay. The Durbin-Watson statistic (1.61), variance inflation factors and tolerance statistics were all within acceptable limits (Table 8). A P-P plot (Figure 4) indicated approximately-normal distribution of residuals. ANOVA demonstrated the final model predicted length of stay significantly better than the mean ($F(5,445)=28.71$, $p<.001$, $r^2=0.244$).

Variables significantly contributing were SI ($t(445)=-7.23$, $p<.001$) and weekly mean individual therapy ($t(445)=-8.11$, $p<.001$). Standardised beta values indicated individual therapy had the largest impact ($\beta=-.36$), followed by SI ($\beta=-.30$). Individual therapy had a negative relationship with length of stay (b=12.86; bootstrap 95% confidence interval -15.89--9.93); i.e. greater individual therapy input was associated with shorter time in inpatient rehabilitation. SI likewise had a negative relationship with length of stay (b=-13.02; bootstrap 95% confidence interval -16.26--9.74).

Table 8. Length of stay statistics from multiple regression.

Variable	Unstandardised B	Standard error	Standardised beta	T	Significance (p)	Collinearity statistics		Bootstrap 95% confidence interval	
						Tolerance	Variance inflation factor	Lower	Upper
Age of onset	-0.28	0.29	-0.04	-0.94	.346	0.93	1.07	-1.00	0.40
Diagnosis	1.31	2.52	0.02	0.52	.605	0.93	1.07	-4.15	7.48
Social Interaction (admission)	-13.02	1.80	-0.30	-7.23	<.001	0.97	1.03	-16.26	-9.74
Individual therapy (weekly mean)	-12.86	1.59	-0.36	-8.11	<.001	0.86	1.16	-15.89	-9.93
Group attendance (weekly mean)	31.33	44.92	0.03	0.70	.486	0.88	1.14	-28.10	143.22

Figure 1. P-P plot of standardised residuals for Motor subscale score change.

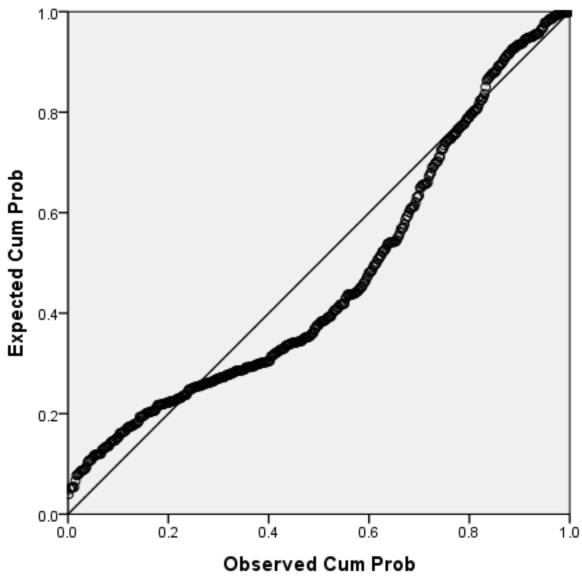


Figure 2. P-P plot of standardised residuals for Cognitive subscale score change.

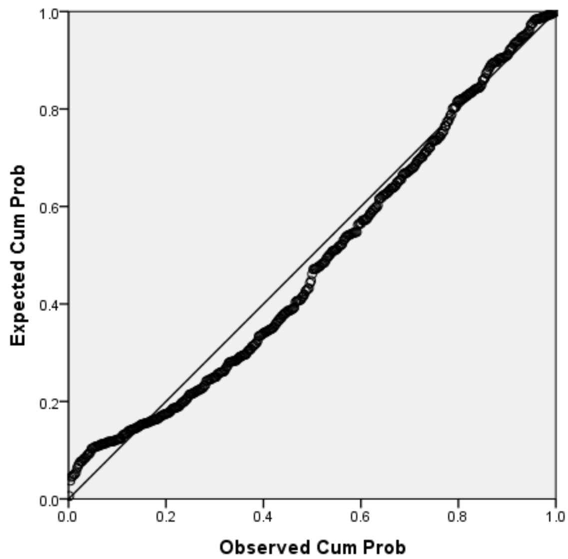


Figure 3. P-P plot of standardised residuals for Total FIM+FAM score change.

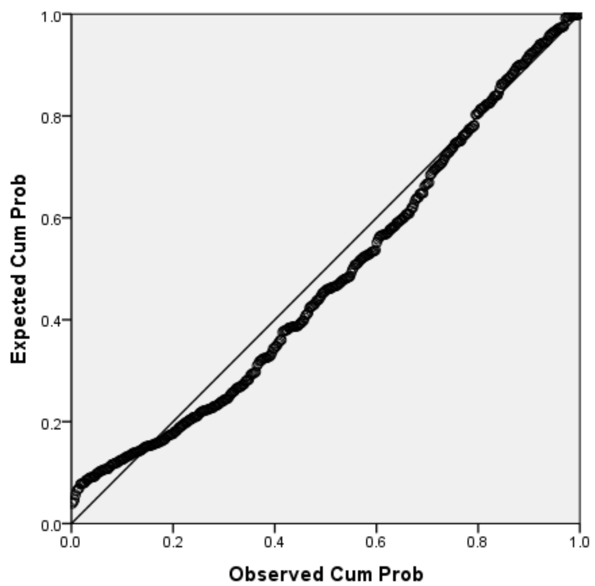
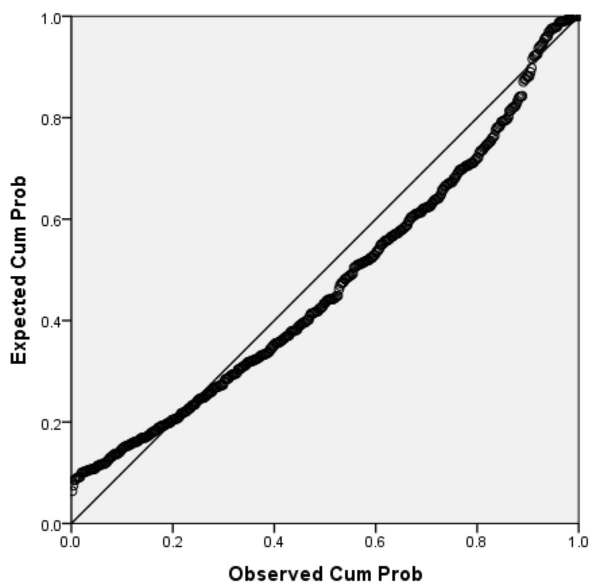


Figure 4. P-P plot of standardised residuals for length of stay.

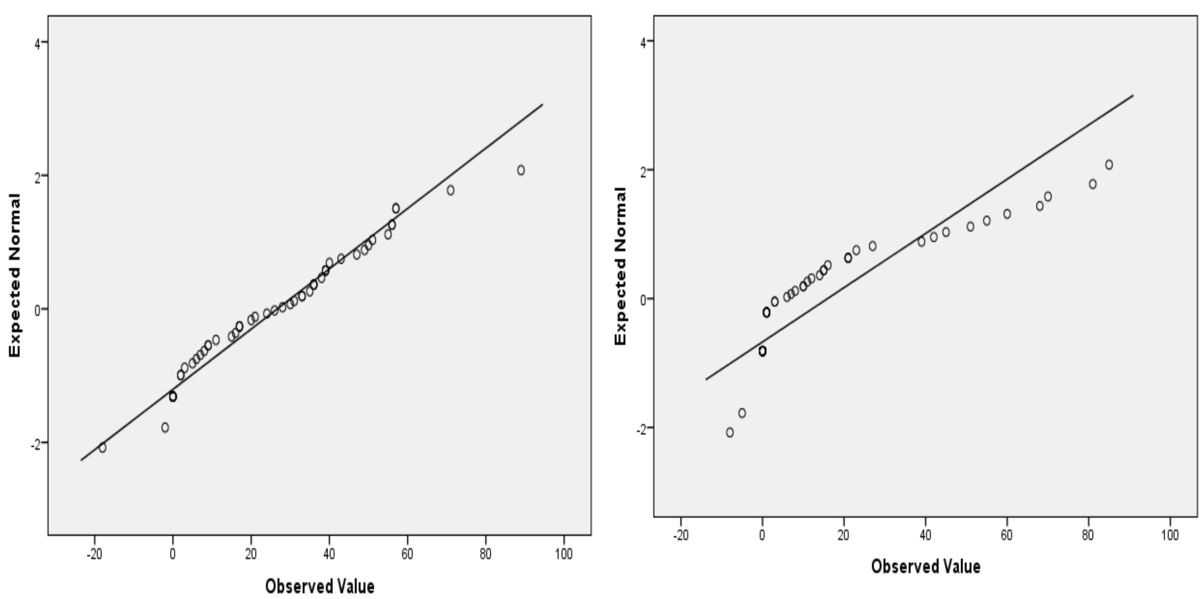


Behaviours of Concern

Differences in Motor/Cognitive/Total FIM+FAM scores and length of stay were evaluated between people exhibiting behaviours of concern, and controls who did not. Bootstrapping was considered as an alternative for these analyses as the data showed non-normal distributions, but since even non-parametric bootstrapping carries assumptions regarding data normality, distribution and bias, it does not compensate for using non-normal data. Therefore, standard non-parametric tests were used instead.

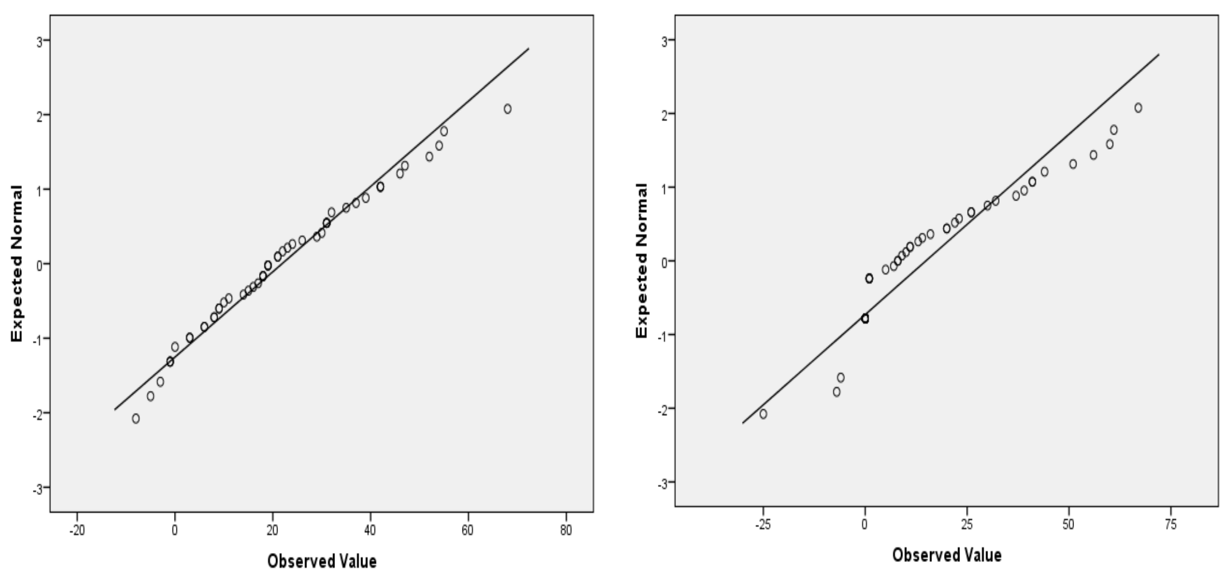
Motor. Motor outcome scores were tested for normality using the Shapiro-Wilk test ($p<.001$), as it has greater sensitivity than the Kolmogorov-Smirnov test (D'Agostino, 1986). Q-Q plots were used for the same purpose (Figure 5). Both methods showed non-normal control distribution, although skewness/kurtosis were acceptable. The non-parametric Mann-Whitney U test was therefore used, which demonstrated that Motor improvement was significantly greater for the behaviours group ($U=887.00$, $p=.002$).

Figure 5. Q-Q plots of quartile distributions for Motor change
(behaviours of concern: left; control groups: right)



Cognitive. The Shapiro-Wilk test and Q-Q plots (Figure 6) showed non-normal Cognitive change score control distribution ($p<.001$), although skewness/kurtosis were acceptable. The Mann-Whitney U test demonstrated that Cognitive improvement was significantly greater for the behaviours group ($U=1015.50$, $p=.028$).

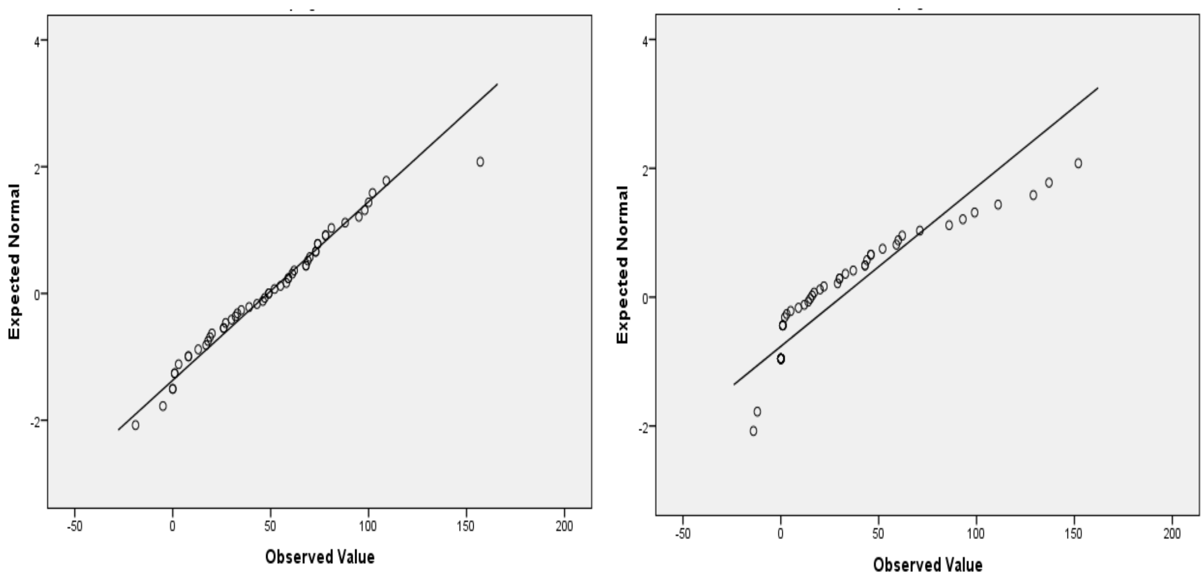
Figure 6. Q-Q plots of quartile distributions for Cognitive change (behaviours of concern: left; control groups: right)



Total. The Shapiro-Wilk test and Q-Q plots (Figure 7) showed non-normal Total change score control distribution ($p<.001$), although skewness/kurtosis were acceptable. The Mann-Whitney U test demonstrated that overall improvement was significantly greater for the behaviours group ($U=879.00$, $p=.002$).

Figure 7. Q-Q plots of quartile distributions for Total change

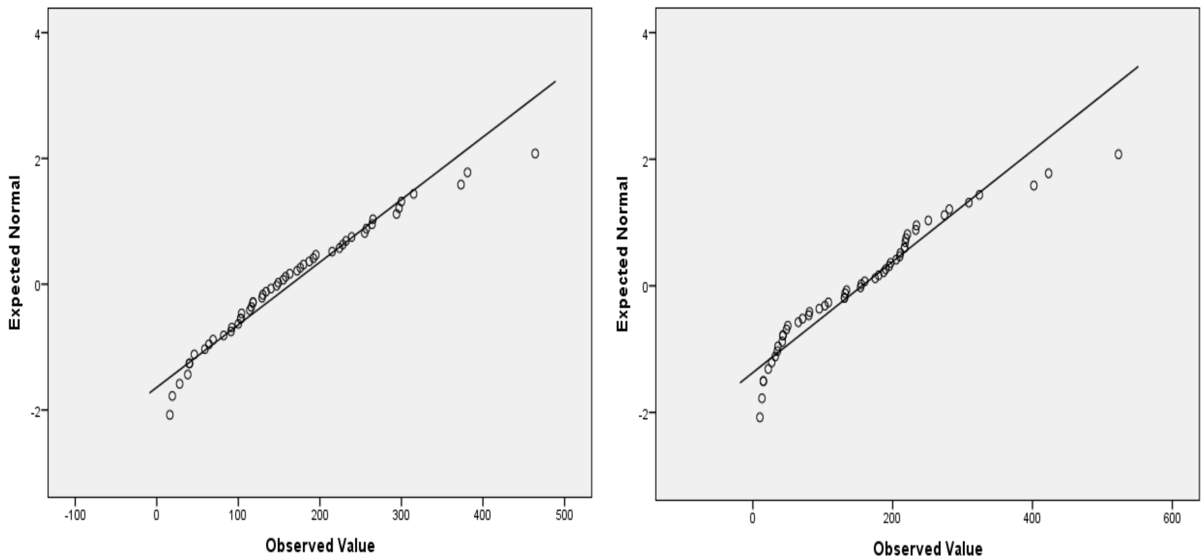
(behaviours of concern: left; control groups: right)



Length of stay. The Shapiro-Wilk test and Q-Q plots (Figure 8) showed non-normal control distribution (p=.002), although skewness/kurtosis were acceptable. The Mann-Whitney U test demonstrated that length of stay did not significantly differ between groups (U=1262.00, p=.561), despite controls having slightly shorter mean length of stay.

Figure 8. Q-Q plots of quartile distributions for length of stay

(behaviours of concern: left; control groups: right)



Relationship between behaviour and on-admission impairment. Analyses indicate that those with behaviours of concern make better gains in recovery. Hypothetically, this might be explained by those exhibiting such behaviours being more likely to have greater initial impairment (and hence greater potential for recovery without encountering FIM+FAM ceiling effects).

Shapiro-Wilk tests and Q-Q plots (Figures 9-11) of Motor/Cognitive/Total admission scores showed non-normal control distributions ($p \leq .001$), although skewness/kurtosis were acceptable. Linear regression was again inappropriate due to the small sample; therefore non-parametric Mann-Whitney U tests were used, which demonstrated no significant difference on admission between the behaviours and control group on Motor ($U=1159.00$, $p=.198$), Cognitive ($U=1293.00$, $p=.698$) or Total scores ($U=1269.00$, $p=.586$).

Figure 9. Q-Q plots of quartile distributions for Motor admission scores (behaviours of concern: left; control groups: right)

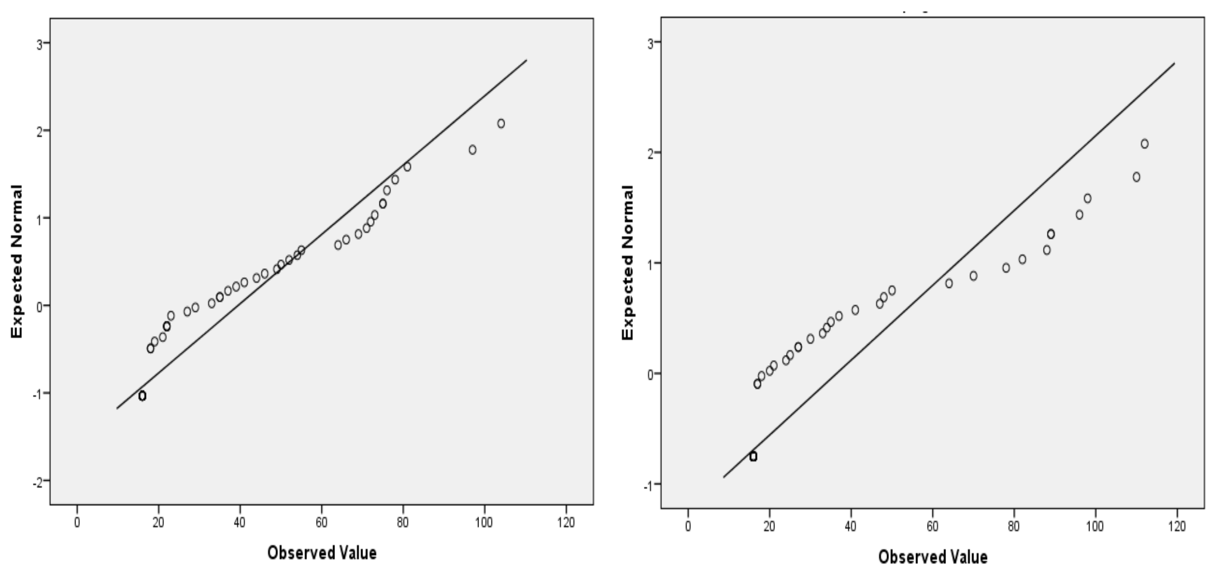


Figure 10. Q-Q plots of quartile distributions for Cognitive admission scores (behaviours of concern: left; control groups: right)

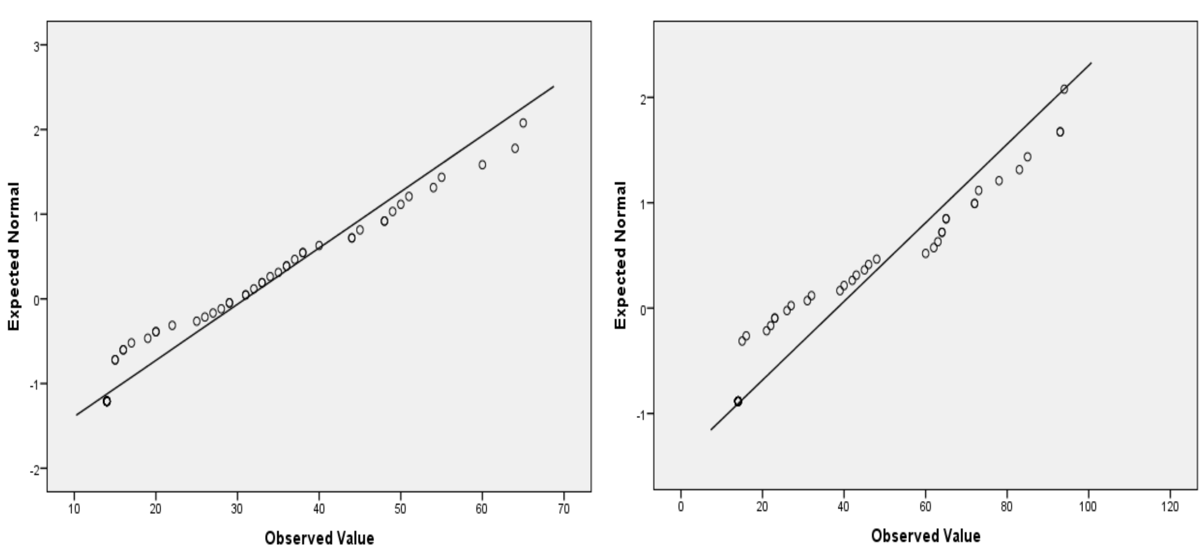
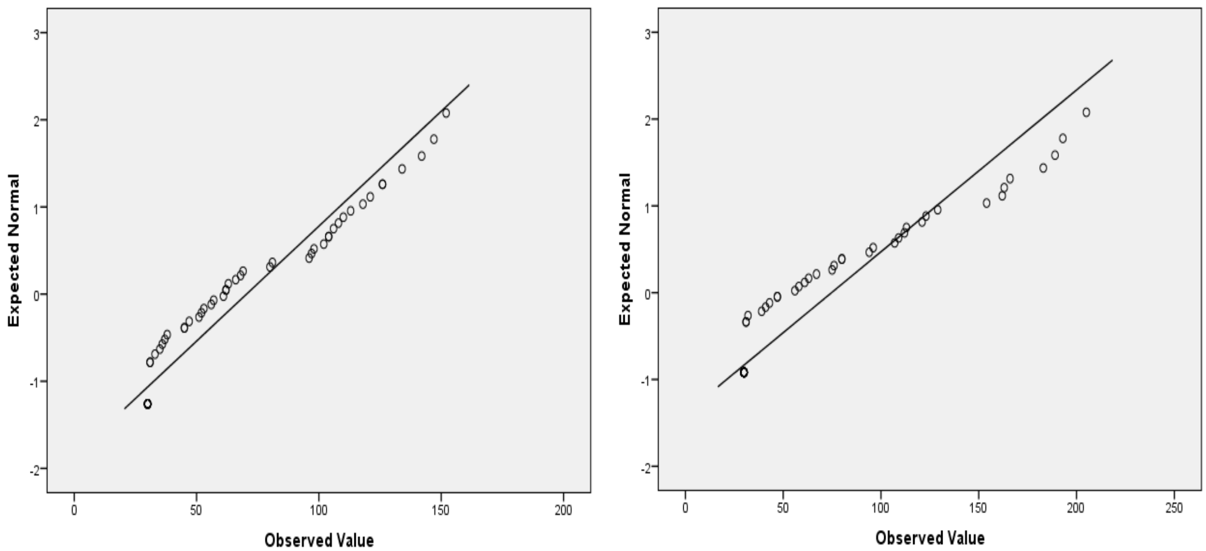


Figure 11. Q-Q plots of quartile distributions for Total admission scores (behaviours of concern: left; control groups: right)



Relationship between behaviour and group activities/individual therapy. Those with behaviours of concern making better rehabilitative gains might be explained by those exhibiting such behaviours receiving more individual and group input, e.g. in attempts to address boredom. Shapiro-Wilk tests and Q-Q plots (Figures 12/13) showed non-normal control distributions for mean weekly individual therapy and group activity ($p \leq .001$); skewness/kurtosis were also not acceptable for the group data. Linear regression was again inappropriate due to the small sample; therefore non-parametric Mann-Whitney U tests were used, which demonstrated no significant difference between the behaviours and control groups on weekly mean individual therapy ($U=1118.00$, $p=.129$) or group activities ($U=1182.00$, $p=.202$).

Figure 12. Q-Q plots of quartile distributions for mean weekly individual therapy hours (behaviours of concern: left; control groups: right)

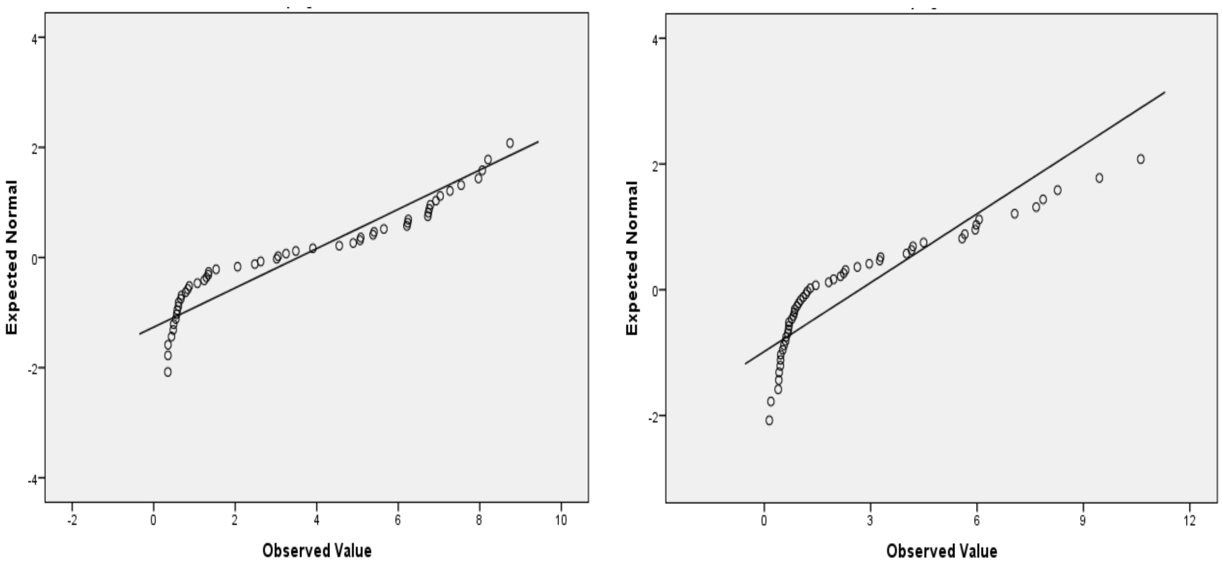
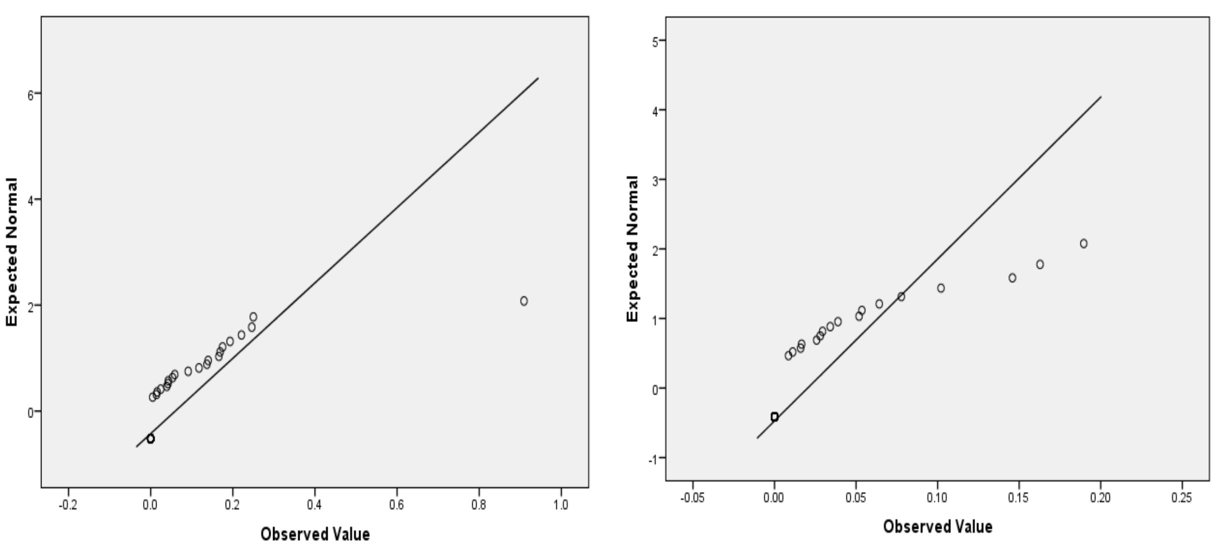


Figure 13. Q-Q plots of quartile distributions for mean weekly group activity hours (behaviours of concern: left; control groups: right)



Discussion

This cohort study evaluated effects of socially-appropriate engagement and behaviours of concern on cognitive, motor, overall and length of stay outcomes of rehabilitation for 469 individuals with complex ABI, as well as convergent/divergent validity between the SI FIM+FAM item and markers of engagement.

Social Interaction: Relationship to Associated Variables

SI correlated positively with weekly mean individual therapy/group activities, and negatively with PCAT ratings of behavioural/cognitive difficulties. It was expected that the measures of positive engagement correlated positively with SI, as SI evaluates both positive ability to interact with peers/therapists, and negative factors such as behaviours of concern which may impede interaction (UK FIM+FAM Users Group, 2010; Winkler et al., 2006). This is further supported by SI correlating inversely with behavioural/cognitive difficulties; individuals with low cognitive/behavioural difficulties are more likely to engage appropriately with peers/healthcare professionals, whereas those with behaviours of concern or cognitive difficulties are less likely to interact positively/appropriately (Dumas et al., 2004; Horn et al., 2005, 2015; Tepas et al., 2009; Wagner et al., 2003). This suggests that SI has good convergent validity with markers of engagement in inpatient settings, and divergent validity with factors preventing engagement.

PCAT emotional difficulty ratings were not significantly related to SI, despite emotional control comprising a key element of SI scoring (UK FIM+FAM Users Group, 2010). This may indicate that despite apparently-overlapping definitions of SI and Emotional Status (both refer to behaviours arising from agitation/frustration), SI focuses on behaviours and Emotional Status on underlying emotional state. This would explain both items being retained in aforementioned FIM+FAM factor analyses, as they have subtly-different foci with independent explanatory value. Alternatively, while behaviour and to a lesser extent cognition are outwardly-observable, it is more difficult to rate another's emotional state, particularly when communication/expression may be impaired and this may affect PCAT emotional rating validity (Alexander, 1997).

Despite correlations being significant and in the expected directions, effect sizes were generally small. A potential explanation is the FIM+FAM's known scoring difficulties relating to Cognitive item abstractness (including SI), which reduce reliability (Alcott et al., 1997; Hall, 1992; McPherson et al., 1996; Turner-Stokes et al., 1999). The PCAT also only evidenced moderate convergent/divergent validity with relevant measures including the overall FIM+FAM on prior assessment (Turner-Stokes et al., 2019), so the small effects are line with prior findings. Alternatively, some aspects of SI were not assessable – information about physical restraint or medication for emotion/behaviour management were not available. These may comprise important predictive components of SI, which could not be assessed in this study. Finally, regarding the group activity/SI relationship, most groups were physical/skills-based and had a lesser social component than speech therapy or psychology-oriented groups (Hammond et al., 2015). This may have weakened the relationship between SI and group activity.

Socially-appropriate Engagement

Effects of weekly mean participation in individual therapy and group activities on Cognitive/Motor/Total functional change and length of stay during intensive inpatient rehabilitation were assessed via multiple regressions, controlling for multiple comparisons and the potentially confounds of injury age and aetiology.

Greater group attendance was associated with greater Motor improvement only. Since most groups were physical skills-based, e.g. dance or exercise groups, this fits prior findings showing positive outcomes for physiotherapy or occupational therapy groups (Coulter et al., 2009; Trahey, 1991), potentially because such groups enable practice of functional skills and strengthening exercises (Hammond et al., 2015). Group effects of belonging, completing tasks and engaging in meaningful collaborative activities have also been highlighted as key in ABI recovery (Gerber & Gargaro, 2015; Häggström & Lund, 2008; Patterson, Fleming, & Doig, 2017; Patterson, Fleming, Doig, et al., 2017), improving social integration and mental health (Masel & DeWitt, 2010) and reducing boredom and behaviours of concern (Gerber & Gargaro, 2015; Kenah et al., 2018), despite difficulties matching group activities to the functional capabilities of diverse inpatient groups (Fuller, 2013). It is important to note that direction of causation is unclear from these data, e.g. an alternative explanation is that those with better physical function are more capable of group participation. However, these findings appear to demonstrate important physical benefits of group activities in inpatient settings, in line with evidence from community environments (Backhaus et al., 2010; Dahlberg et al., 2007; Lundgren & Persechino, 1986).

Conversely, greater mean weekly individual therapy participation was associated with shorter length of stay, but also poorer Motor/Cognitive/Total recovery. This contrasts with prior evidence demonstrating improved outcomes resulting from greater individual therapy in ABI rehabilitation (Blackerby, 1990; Carney et al., 1999; Cicerone et al., 2008; Cifu et al., 2003; Cullen et al., 2007; Shiel et al., 2001; Spivack et al., 1992; Turner-Stokes et al., 2015), but concurs with one study finding no significant effect of therapy intensity (Zhu et al., 2007). One potential explanation is that more functionally-capable people received more individual therapy, so a ceiling effect may have reduced gains for those receiving more input. A further hypothesis is that total time in individual therapy is too broad a measure, since outcomes may also be therapy complexity-dependent (Dumas et al., 2004; Horn et al., 2005, 2015; Tepas et al., 2009; Wagner et al., 2003), and therapy intensity provides decreasing returns over time (Cullen et al., 2007); the type of therapy and period of provision may therefore mediate any relationship.

Adding further complexity, previous research shows a discipline-dependent 'trade-off' between group and individual therapy provision. In physiotherapy and occupational therapy, groups are frequently used to achieve the same aims as individual work and individual input is consequently reduced, whereas more group work is associated with more individual input in psychology, speech therapy and recreational groups (Hammond et al., 2015; Zanca et al., 2013). Individual and group therapy may also interact to generate optimum gains. One could therefore potentially be removed as a predictor due to interaction with the other, confounding effects of individual therapy (Vestri et al., 2014).

Injury type was predictive of Total and Cognitive outcomes; individuals with anoxic ABI demonstrated poorer recovery in both analyses than people with traumatic ABI and ABI by stroke (infarct/haemorrhage). This suggests that more diffuse injury carries poorer cognitive improvement than focal injury, matching findings by (Gunn & Burgess, submitted) and potentially attributable to impaired neuroplastic recovery in more widespread damage (Stinear, 2010) – although Gunn et al. (2018) found no overall differences in outcomes between focal/diffuse injury, so this area remains contested. While the nationally-used diagnostic categories in this study create good generalisability, categorising diagnoses may also be problematic, as highly-specific diagnoses may carry different outcomes and broad categories may mask important differences (Ween et al., 1996). Focal/diffuse categorisations may also create a false dichotomy, as e.g. primarily-focal injuries such as specific trauma may also generate diffuse axonal injury (Nayar et al., 2016). Finally, while injury type may have predictive value, care must be taken to maintain focus on individual difficulties and not diagnosis (as has happened to the detriment of individualised intervention in learning disability, where difficulty-focused approaches may be more meaningful (Astle et al., 2019).

Greater age was associated with poorer Motor and overall improvement. This is consistent with previous findings that age predicts recovery (Alexander, 1994; Balestreri et al., 2004; Dawson & Chipman, 1995; Gray & Burnham, 2000; Lehmann et al., 1975; Macciocchi et al., 1998; Nakayama et al., 1994; Ponsford et al., 1995; Rothweiler et al., 1998), including findings that age predicts physical but not cognitive/psychosocial recovery (Nakayama et al., 1994; Wood & Rutterford, 2006). However, this conflicts with other findings that age is unrelated to recovery (Bonita & Beaglehole, 1988; Hoofien et al., 2002; Tate et al., 2005) or that it influences recovery differentially or not at all between age groups (Hankey et al., 2007; Himanen et al., 2006; Kelly et al., 2003; Ween et al., 1996). Overall, however, the current study's finding was consistent with the majority of studies.

Finally, higher on-admission SI was associated with greater Motor and overall improvement, and with shorter length of stay in rehabilitation. This seems reasonable, as individuals with few cognitive/behavioural difficulties are more able to access and benefit from individual therapy and group activities, whereas those with low frustration tolerance and poorer resilience/coping may be offered fewer opportunities and be less able to tolerate challenges, reducing overall improvement (Dumas et al., 2004; Horn et al., 2005, 2015; Tepas et al., 2009; Wagner et al., 2003). SI provided additional predictive value beyond individual therapy and group activities; as noted previously, some aspects of SI were not available from the data, and these may comprise the difference.

Behaviours of Concern

Controls made significantly less improvement on Motor, Cognitive and overall FIM+FAM outcomes then the behaviours group. This was a surprising outcome, as those with behaviours of concern were expected to make poorer improvement. Analysis of between-group differences in FIM+FAM admission scores showed no significant differences, dismissing the hypothesis that those with greater functional impairment are more likely to exhibit behaviours relating to frustration/agitation (Alderman, 2003; Ryan et al., 2015).

Somewhat in line with predictions, mean length of stay was non-significantly shorter for controls, in line with the hypothesis that people with behaviours of concern may be harder to discharge to home or suitable community placements (Tam et al., 2015; Winkler et al., 2006); with an appropriately-powered sample, this might have registered as significant. The longer length of stay might partially explain the non-significantly greater rehabilitation gains.

Behaviours of concern having no detrimental effect on outcomes is surprising but promising, suggesting that behavioural difficulties may not impair therapeutic improvement; involvement in such activities may even promote engagement and reduce such behaviours (Gerber & Gargaro, 2015). Much of this may be due to dedication from rehabilitation staff who persist in offering therapy/activities, evidenced by the lack of significant difference in amount of therapy/activities between groups. In fact, the behaviours group received non-significantly more group and individual time, which might have been significant in an appropriately-powered study and potentially even contributed to the additional improvement in that group.

Limitations

Several limitations recommend that findings be treated with caution. In terms of sampling bias, use of a mixed-ABI sample creates ecological validity and enables generalisation of findings to other inpatient rehabilitation units, but limits applicability to specific ABI aetiologies. Derivation of data from a single unit also limits generalisability to other units (Jongbloed, 1986). Additionally, the focus on an inpatient unit limits generalisability to outpatient or community settings due to different rehabilitation foci in these populations (Gray et al. , 1994; Kilgore, 1995; Powell, 1999, 2002). The sample was also male-biased (62.8% male), which while representative of higher ABI risk in males (Bruns & Hauser, 2003; Elkind & Sacco, 1998) reduces applicability of findings to females in whom different rehabilitation outcomes have been reported (Adams et al., 2004). Finally, sample was almost exclusively white European; consequently, due to different mean rehabilitative outcomes in other populations, findings are again not generalisable (Bhandari et al., 2005; Ottenbacher et al., 2008).

In terms of measures, clinician-only report has certain merits. Individuals with ABI may have difficulties with memory/cognition/communication which prevent accurate scoring, and clinicians typically have greater contact with individuals than relatives (and possibly more current understanding of their wellbeing). However, failing to gather information from individuals and relatives may well neglect important perspectives on social/emotional/personality changes (Alexander, 1997; Jackson et al., 1992; Milders et al., 2003; Tate, 1999).

Regarding study design, retrospective data analysis crucially permitted access to a large database and consequently appropriately-powered analyses; however, it also limited methodological and measure-related flexibility and risks greater inaccuracy than direct data-gathering (Nayar et al., 2016). The behaviour data were also potentially problematic, as the behaviours group were a specific subset monitored/documented due to high risk and may not represent all individuals with behaviours of concern. Additionally, the assumption that controls exhibited no behaviours of concern due to lack of recordings and low consultant behavioural risk ratings may be unreliable, as may the assumption that recordings were consistent/accurate on busy wards with high staff turnover. The analyses were also underpowered, so differentiation between effects of different behaviours of concern was not possible.

Finally, while nonparametric analyses were selected where normality assumptions were violated as these are unaffected by skewness, some authors argue that parametric analyses offer better generalisability even for non-normal data (Altman & Bland, 2009; Hawley et al., 1999; Tabachnick & Fidell, 2007; Turner-Stokes & Siegert, 2013). Others contend that psychological/behavioural rating scales are not truly comparable to interval scales, and therefore standard statistical analyses are inappropriate (Baker et al., 1966; Cohen & Cohen, 2003; Hawley et al., 1999; Wright & Masters, 1982), although the vast majority of studies of predictors use standard analyses (e.g. regression) as in this study. Acknowledgement of these debates is, however, important for context. For full discussion of limitations, see Appendix S.

Clinical Implications

These findings support the continued use of the SI FIM+FAM item, which has good convergent validity with ecologically-valid markers of individual/group engagement, and consultant ratings of cognitive/behavioural difficulties. It also has predictive value around motor/overall improvement, and length of inpatient stay. These findings indicate that SI makes a useful contribution to the rehabilitation assessment process.

The positive association between mean hours of group activities and motor outcomes indicates that access to physical skills-based groups may benefit functional recovery. Inpatient ABI rehabilitation services should prioritise access to such groups, which are also cost-effective and provide social/motivation/behavioural benefits (Gerber & Gargaro, 2015; Häggström & Lund, 2008; Kenah et al., 2018; Masel & DeWitt, 2010; Patterson, Fleming, & Doig, 2017; Patterson, Fleming, Doig, et al., 2017).

Findings indicated that those with behaviours of concern may remain in hospital for longer, which may confer benefits to outcomes, but is associated with greater risk (Schimmel, 2003). Inpatient rehabilitation services should therefore examine and address reasons underlying slower discharge, e.g. those with behaviours of concern may be more difficult to place in safe/appropriate environments (Tam et al., 2015; Winkler et al., 2006).

While retrospective data use opens up large clinical samples, multivariate model accuracy is typically inflated with retrospective data. Confirmatory prospective studies regarding these findings would be prudent before enacting clinical recommendations. It is however positive that the models generated in this study are reasonably simple, and therefore more easily clinically applicable, which is often untrue of complex multivariate models (Gladman et al., 1992). It is however essential to ensure that findings indicating poorer outcomes across groups are not interpreted as comprising predictions about individuals, which might risk creating self-fulfilling prophecies (Stinear, 2010). For more on clinical implications, see Appendix T.

Future Research

Further studies of the role of behaviours of concern are required, as this study was underpowered and could not differentiate between behavioural types, nor could it identify effects of groups on behaviour frequency/severity as seen elsewhere (Gerber & Gargaro, 2015). Studies of whether better gains persist for those exhibiting such behaviours once in the community, without inpatient support, would be informative (Tam et al., 2015).

Examination of whether therapy complexity (Dumas et al., 2004; Horn et al., 2005, 2015; Tepas et al., 2009; Wagner et al., 2003), discipline (Cifu et al., 2003), and duration mediate any effect of individual therapy would be important (Cullen et al., 2007), as many studies have identified positive roles for individual input in rehabilitation (Carney et al., 1999; Cicerone et al., 2008; Cullen et al., 2007; Turner-Stokes et al., 2015) and these variables may have confounded this study's results. Similarly, exploration of whether group type, lead therapeutic discipline or intensity contributed to gains would be valuable, as would identifying whether groups provide similar/better outcomes to individual therapy while being more cost-effective.

Exploring outcome differences between aetiologies further may also be helpful, and evaluating differential outcomes relating to race/ethnicity and education level is essential (Bhandari et al., 2005; Fernandes et al., 2012; Ottenbacher et al., 2008). Finally, studies should comprise prospective multicentre studies to address limitations on generalisability from a single unit/population (Gladman et al., 1992; Nayar et al., 2016) and to assess how well the models identified in this study generalise to non-inpatient settings. For further discussion of future research aims, see Appendix U.

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APPENDICES

Mandatory appendices marked by an asterisk *

Appendix A: Guidelines for journal (literature review submission)*

Disability and Rehabilitation

Aims and scope

(https://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=IDRE20)

Disability and Rehabilitation along with *Disability and Rehabilitation: Assistive Technology* are international multidisciplinary journals which seek to encourage a better understanding of all aspects of disability and to promote rehabilitation science, practice and policy aspects of the rehabilitation process.

Disability and Rehabilitation publishes Reviews, Research Papers, along with sections on Rehabilitation in Practice, Perspectives in Rehabilitation and Case Studies along with occasional Letters. There are two new sections, one on Assessment Procedures and the other on Education and Training.

Submissions covering a wide range of topics on disability and rehabilitation from researchers and practitioners across all disciplines working in the field are encouraged. The journals welcome both quantitative and qualitative research along with multidisciplinary perspectives to embrace a wide range of professionals. Both journals also publish peer-reviewed special issues as appropriate.

About the journal

(https://www.tandfonline.com/action/authorSubmission?journalCode=idre20&page=instructions)

Disability and Rehabilitation is an international, peer reviewed journal, publishing high-quality, original research. Please see the journal's Aims & Scope for information about its focus and peer-review policy.

Disability and Rehabilitation accepts the following types of article: Reviews, Research Papers, Case Studies, Perspectives on Rehabilitation, Reports on Rehabilitation in Practice, Education and Training, and Correspondence. Systematic Reviews should be submitted as "Review" and Narrative Reviews should be submitted as "Perspectives in Rehabilitation".

Preparing your paper

All authors submitting to medicine, biomedicine, health sciences, allied and public health journals should conform to the Uniform Requirements for Manuscripts Submitted to Biomedical Journals, prepared by the International Committee of Medical Journal Editors (ICMJE).

We also refer authors to the community standards explicit in the American Psychological Association's (APA) Ethical Principles of Psychologists and Code of Conduct.

We encourage authors to be aware of standardised reporting guidelines below when preparing their manuscripts:

- Case reports - CARE
- Diagnostic accuracy - STARD
- Observational studies - STROBE
- Randomized controlled trial - CONSORT
- Systematic reviews, meta-analyses - PRISMA

Whilst the use of such guidelines is supported, due to the multi-disciplinary nature of the Journal, it is not compulsory.

Structure

Your paper should be compiled in the following order: title page; abstract; keywords; main text, introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s); figures; figure captions (as a list).

Appendix A (continued): Guidelines for journal (literature review submission)*

Disability and Rehabilitation

In the main text, an introductory section should state the purpose of the paper and give a brief account of previous work. New techniques and modifications should be described concisely but in sufficient detail to permit their evaluation. Standard methods should simply be referenced. Experimental results should be presented in the most appropriate form, with sufficient explanation to assist their interpretation; their discussion should form a distinct section.

Tables and figures should be referred to in text as follows: figure 1, table 1, i.e. lower case. The place at which a table or figure is to be inserted in the printed text should be indicated clearly on a manuscript. Each table and/or figure must have a title that explains its purpose without reference to the text.

The title page should include the full names and affiliations of all authors involved in the preparation of the manuscript. The corresponding author should be clearly designated, with full contact information provided for this person.

Word count

Please include a word count for your paper. There is no word limit for papers submitted to this journal, but succinct and well-constructed papers are preferred.

Style guidelines

Please refer to these style guidelines when preparing your paper, rather than any published articles or a sample copy.

Please use any spelling consistently throughout your manuscript.

Please use double quotation marks, except where "a quotation is 'within' a quotation". Please note that long quotations should be indented without quotation marks.

For tables and figures, the usual statistical conventions should be used.

Drugs should be referred to by generic names. Trade names of substances, their sources, and details of manufacturers of scientific instruments should be given only if the information is important to the evaluation of the experimental data.

Formatting and templates

Papers may be submitted in any standard format, including Word and LaTeX. Figures should be saved separately from the text. To assist you in preparing your paper, we provide formatting template(s).

Word templates are available for this journal. Please save the template to your hard drive, ready for use.

A LaTeX template is available for this journal. Please save the template to your hard drive, ready for use.

If you are not able to use the templates via the links (or if you have any other template queries) please contact us here.

References

Please use this reference guide when preparing your paper. An EndNote output style is also available to assist you.

Appendix B: Checklist to ensure anonymity of clients/services*

	Checked in Executive Summary/Abstract/ Overview (if included in assignment)	**Checked in main text**	**Checked in appendices**
Pseudonym or false initials used	x	x	x
Reference to pseudonym/false initials as a footnote	x	x	x
Removed any reference to names of Trusts/hospitals/clinics/services (including letterhead if including letters in appendices)	x	x	x
Removed any reference to names/specific dates of birth/specific date of clinical appointments/addresses/ location of client(s), participant(s), relatives, caregivers, and supervisor(s). [For research thesis – supervisors can be named in the research thesis "acknowledgements" section]	x	x	x
Removed/altered references to client(s) jobs/professions/nationality where this may potentially identify them. [For research thesis – removed potential for an individual research participant to be identifiable (e.g., by a colleague of the participant who might read the thesis on the internet and be able to identify a participant using a combination of the participants specific job title, role, age, and gender)]	x	x	x
Removed any information that may identify the trainee (consult with course staff if this will detract from the points the trainee is making)	x	x	x
No Tippex or other method has been used to obliterate the original text – unless the paper is subsequently photocopied and the trainee has ensured that the obliterated text cannot be read	x	x	x
The "find and replace" function in word processing has been used to check the assignment for use of client(s) names/other confidential information	x	x	x

Appendix C: Functional Independence Measure and Functional Assessment Measure*

FIM/FAM items (subscale as per manual)	Score range or options
1. Eating (MOTOR)	1-7
2. Swallowing (MOTOR)	1-7
3. Grooming (MOTOR)	1-7
4. Bathing (MOTOR)	1-7
5. Dressing Upper Body (MOTOR)	1-7
6. Dressing Lower Body (MOTOR)	1-7
7. Toileting (MOTOR)	1-7
8.1. Bladder (assistance) (MOTOR)	1-7
8.2. Bladder (frequency) (MOTOR)	1-7
9.1. Bowel (assistance) (MOTOR)	1-7
9.2. Bowel (frequency) (MOTOR)	1-7
10. Bed/chair transfer (MOTOR)	1-7
11. Toilet transfer (MOTOR)	1-7
12. Tub/shower transfer (MOTOR)	1-7
13. Car transfer (MOTOR)	1-7
14.1. Locomotion (walking) (MOTOR)	1-7
14.2. Locomotion (wheelchair) (MOTOR)	0-6
Most frequent mode of locomotion	walking (w) or chair (c)
15. Stairs (MOTOR)	1-7
16. Community mobility (MOTOR)	1-7
Usual mode of travel:	car (c), taxi (t) or public transport (p)
17. Comprehension (COGNITIVE)	1-7
18. Expression (COGNITIVE)	1-7
19. Reading (COGNITIVE)	1-7
20. Writing (COGNITIVE)	1-7
21. Speech intelligibility (COGNITIVE)	1-7
22. Social interaction (COGNITIVE)	1-7
23. Emotional status (COGNITIVE)	1-7
24. Adjustment to limitations (COGNITIVE)	1-7
25. Leisure activities (COGNITIVE)	1-7
26. Problem solving (COGNITIVE)	1-7
27. Memory (COGNITIVE)	1-7
28. Orientation (COGNITIVE)	1-7
29. Concentration (COGNITIVE)	1-7
30. Safety awareness (COGNITIVE)	1-7

Reference

UK FIM+FAM Users Group. (2010). The UK FIM+FAM (Functional Assessment Measure) [manual]. Retrieved August 27, 2017, from https://www.kcl.ac.uk/lsm/research/divisions/cicelysaunders/resources/FIMFAM-manual-v2.2-Sept-2012-print-double-sided.pdf

Appendix D: Literature search details*

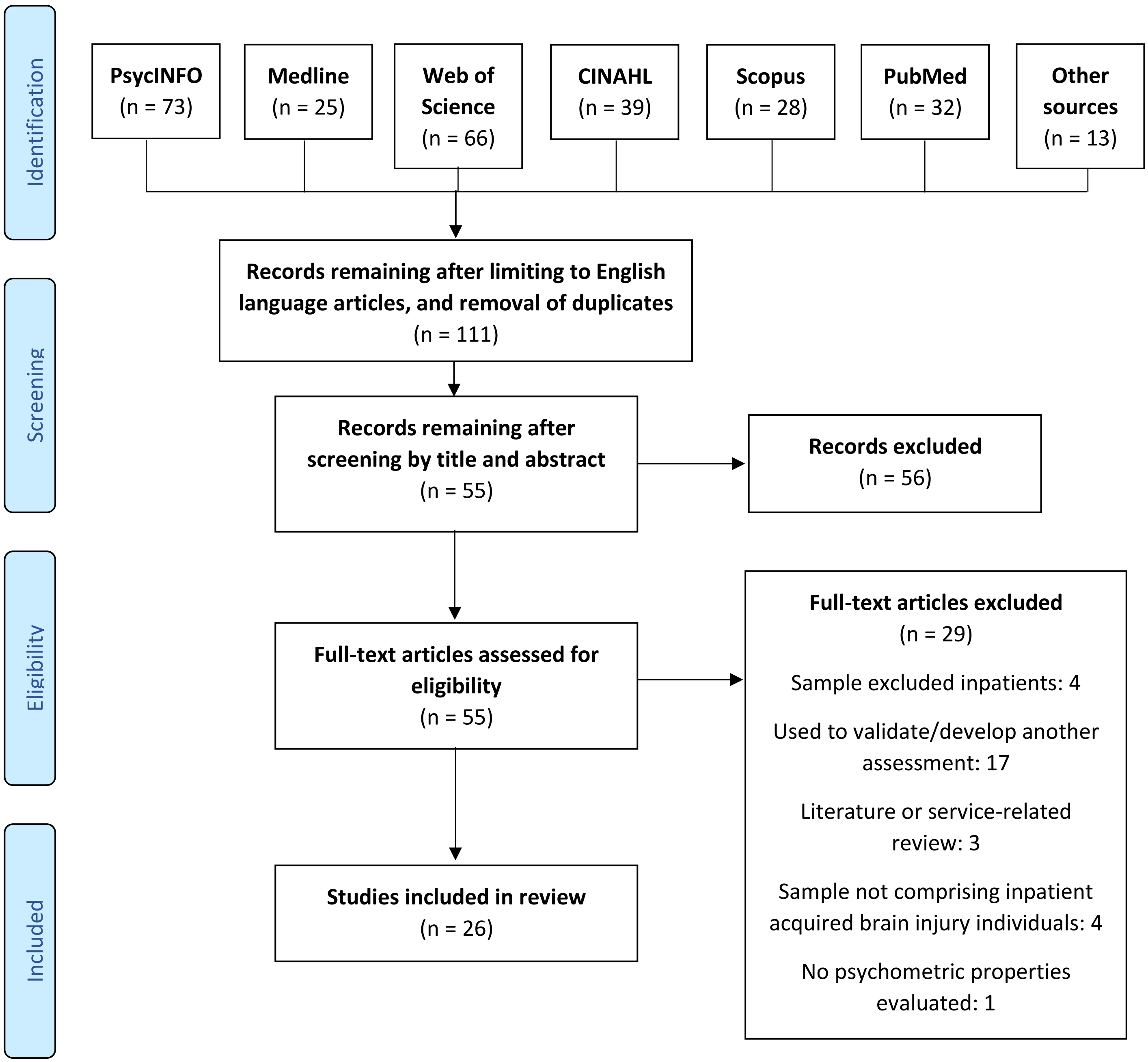
Table 1. Search terms.

Measure terms	AND	Outcome terms
"Functional Independence Measure" AND "Functional Assessment Measure" (OR)		Reliability (OR)
FIM AND FAM		Validity (OR)
		Factor (OR)
		Psychometric

Table 2. Inclusion and exclusion criteria for study selection.

	Inclusion criteria	Exclusion criteria
Population	Humans of any age, of whom at least one group were admitted for inpatient neurorehabilitation At least some participants have diagnosis of acquired brain injury	Non-human participants No participants with diagnosis of acquired brain injury
Outcomes	Examining any aspect of reliability, validity, factor structure or any other psychometric property of the FIM+FAM	FIM+FAM only used as observational or experimental outcome measure FIM+FAM only used to validate another measure No examination of psychometric properties
Study design	Prospective or retrospective Cross-sectional or longitudinal Peer-reviewed journal article English-language study No date limitations	Review article Qualitative study Discursive piece Non-English language studies

Appendix E: Study selection process



Appendix F: COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) checklist – front summary page*

Instructions

Tick the boxes that need to be completed for the article

	COSMIN Risk of Bias checklist
	Box 1. PROM development
	Box 2. Content validity
	Box 3. Structural validity
	Box 4. Internal consistency
	Box 5. Cross-cultural validity\Measurement invariance
	Box 6. Reliability
	Box 7. Measurement error
	Box 8. Criterion validity
	Box 9. Hypotheses testing for construct validity
	Box 10. Responsiveness

To assess the methodological quality of each study, i.e. assessing the risk of bias of the result of a study, the corresponding COSMIN Risk of Bias box should be completed. To determine the overall quality of a study the lowest rating of any standard in the box is taken (i.e. "the worst score counts" principle). For example, if for a reliability study one item in a box is rated as 'inadequate', the overall methodological quality of that reliability study is rated as 'inadequate'. The response option 'NA' (not applicable) is at issue for some standards. For example, when a s:udy on structural validity is based on CTT, the standard on IRT is not applicable and this standard should not be considered in the "worst score counts"-rating for that specific study. For standards where this option is not at issue, these cells are grey and shouldn't be used.

Reference

Mokkink, L. B., de Vet, H. C. W., Prinsen, C. A. C., et al. (2018). COSMIN Risk of Bias checklist for systematic reviews of Patient-Reported Outcome Measures. *Quality of Life Research*, *27*(5), 1171-1179. doi: 10.1007/s11136-017-1765-4.

Appendix G: Data extraction tool for literature review*

Sample	Sampling methodology	
	Recruitment service(s)	
	Sample size	
	Sample age (mean, standard deviation)	
	Gender	
	Country of study	
Design	Psychometric properties evaluated	
	Statistic methodology	
	Other measures included and role (e.g. convergent or divergent validity)	
	Confounds reported/included in analysis	
	Power analysis conducted (yes/no)	
	Limitations highlighted by authors	
	Corrections for multiple analyses (if relevant) (yes/no)	
Results	Key results relevant to measure	

Appendix H: Main aims/results of included studies

Psychometric characteristics evaluated	Study	Specific area of investigation	Statistical methodology	Key results relevant to FIM+FAM	COSMIN rating
Structural validity	Gunn et al. (2018)	UK FIM+FAM factor structure.	EFA; CFA.	Three-factor bifactor model provided best fit: general function factor; 3 group factors (motor, psychosocial and communication).	VERY GOOD
Structural validity	Hawley et al. (1999)	Factor structure.	Principal components analysis.	Two-factor solution (physical and cognitive) explained 44% (physical) and 40% (cognitive) of variance.	ADEQUATE
Structural validity	Nayar et al. (2016)	UK FIM+FAM factor structure.	EFA; CFA.	Three-factor solution (69% variance): motor (15 items), psychosocial (9 items) and communication (5 items).	VERY GOOD
Structural validity	Turner-Stokes & Siegert (2013)	Factor structure of UK FIM+FAM.	Exploratory PCA; confirmatory Mokken analysis.	PCA: motor and cognitive domains emerged. Mokken analysis: 4-factor solution (physical, psychosocial, communication, EADL).	DOUBTFUL
Content validity	Alcott et al. (1997)	"Imageability" (abstractness) of FIM and FAM keywords using 7-point Likert scale.	Friedman's two-way ANOVA; Wilcoxon matched-pairs signed-ranks test.	No significant differences between pairs of motor/cognitive keywords. *Keyword imageability range:* - Motor: 6.02-6.59. - Cognitive: 2.00-3.02.	ADEQUATE
Content validity	Law et al. (2009)	UK FIM+FAM EADL: effect of ambiguous vignettes on other psychometric properties.	Weighted Cohen's kappa.	*Ambiguous vignettes*: excellent team/individual intrarater reliability/accuracy; excellent team interrater reliability; good individual interrater reliability.	VERY GOOD
Content validity (floor/ceiling effects)	Austin et al. (2018)	Floor and ceiling effect for UK FIM+FAM.	Frequencies analysis.	*Ceiling and floor effects:* Total: floor 6.9%, ceiling none Motor: floor 11.1%, ceiling 1.4% Cognitive: floor 13.9%, ceiling none	Not assessed by COSMIN

Psychometric characteristics evaluated	Study	Specific area of investigation	Statistical methodology	Key results relevant to FIM+FAM	COSMIN rating
Content validity (floor/ceiling effects)	Bajo et al. (1999)	Ceiling effects.	Percentage reaching maximal scores reported.	Not for FIM, self-care and mobility subscales *Ceiling effects:* self-care (76% at ceiling), mobility (79%)	Not assessed by COSMIN
Content validity (floor/ceiling effects)	Hall et al. (1996)	FIM+FAM ceiling effects, and compared with FIM.	% cases scoring mean 6-7.	*% of patients scoring mean 6-7:* At discharge: FIM: 49%; FIM+FAM: 34%. One year post-injury: FIM: 84%; FIM+FAM: 79%. *Precision/variance:* 4/12 FAM items offered more precision (median <7) and variance (interquartile range: 2+ quartiles) than 16/18 FIM items at years 1 and 2 post-injury.	Not assessed by COSMIN
Content validity (floor/ceiling effects)	Hobart et al. (2001)	Score variability.	Means reported without analysis.	FIM+FAM score variability: Total: 32-204, mean 144.8 Motor: 17-110, mean 71.0 Cognitive: 15-98, mean 73.8	Not assessed by COSMIN
Content validity (floor/ceiling effects)	Linn et al. (1999)	Range of FIM and FAM item difficulty for Motor and Cognitive subscales; criterion validity.	Percentage scoring ≥6.0 or 2.0≥ mean.	*Ceiling effects* (% scoring ≥6.0): FIM: 18-30% (admission); 40-54% (discharge). FIM+FAM: 14-23% (admission); 40-54% (discharge). *Floor effects* (% scoring 2.0≥): <5%.	Not assessed by COSMIN
Content validity (floor/ceiling effects)	McPherson and Pentland (1997)	FIM+FAM ceiling effect.	Percentage achieving maximal score reported.	*% gaining maximal scores:* FIM+FAM: 2%	Not assessed by COSMIN
Content validity (floor/ceiling effects)	McPherson et al. (1996)	FIM+FAM ceiling effect.	Number achieving maximal score on all items reported.	No participant achieved maximal scores on all FIM+FAM items	Not assessed by COSMIN

Psychometric characteristics evaluated	**Study**	**Specific area of investigation**	**Statistical methodology**	**Key results relevant to FIM+FAM**	**COSMIN rating**
Content validity (floor/ceiling effects)	Wilson et al. (2009)	UK FIM+FAM ceiling effects.	F tests	*Motor subscale ceiling effects:* mean at ceiling: 43.3% (admission; range 7-90%) and 61.7% (discharge; range 23-94%). ≥50% at ceiling on 4/16 items (admission); 13/16 (discharge). *Cognitive subscale ceiling effects:* mean at ceiling: 48.3% (admission; range 4-70%) and 56.4% (discharge; range 19-77%). ≥50% at ceiling on 9/14 items (admission) and 11/14 (discharge).	Not assessed by COSMIN
Internal consistency	Hawley et al. (1999)	Internal consistency.	Rasch analysis.	Physical subscale: α=0.99. Cognitive subscale: α=0.98 Total FIM+FAM: α=0.99. 4 physical, 3 cognitive items missed desirable infit/outfit ranges.	VERY GOOD
Internal consistency	Hobart et al. (2001)	FIM+FAM, BI and FIM internal consistency.	Corrected item-total correlations; mean interitem correlations; alpha coefficients; Pearson's *r*; SRM.	*Consistency:* corrected item-total correlations >0.4, mean interitem correlations >0.3, alphas >0.8.	VERY GOOD
Internal consistency	Nayar et al. (2016)	UK FIM+FAM internal consistency in subscales developed via factor analysis	Cronbach's alpha.	*Factor internal consistency:* Motor: .97. Psychosocial: .93. Communication: .88. Total scale: .96.	VERY GOOD
Internal consistency	Turner-Stokes & Siegert (2013)	Internal consistency.	H coefficients.	*H coefficients:* (>.50: strong) total (.64); motor domain (.82); cognitive domain (.65); 4 subscales (.67-.82). *Internal consistency:* total (.98); motor domain (.97); cognitive domain (.96); subscales: physical (.97); psychosocial (.95); communication (.92); EADL (.90).	VERY GOOD
Reliability	Donaghy and Wass (1998)	FIM+FAM interrater reliability.	Intraclass correlation coefficients via one-way ANOVA.	25 items "excellent" (.75-1.00), 4 "good" (.60-.74), 1 (Social Interaction) "poor" (<.40). All subscales excellent except psychosocial (good: .63).	ADEQUATE

Psychometric characteristics evaluated	Study	Specific area of investigation	Statistical methodology	Key results relevant to FIM+FAM	COSMIN rating
Reliability	Hobart et al. (2001)	Intrarater reproducibility; validity (concurrent, convergent, discriminant).	Mean interitem correlations; alpha coefficients; Pearson's *r*; SRM.	Score variability good for all measures; means near midpoint; small floor/ceiling effects *Reliability:* internal consistency and intrarater reproducibility similar across scales. *Validity:* measures of same functions highly correlated (r=.96-.996) and high intraclass correlation coefficients (.95-.995).	DOUBTFUL
Reliability	Hall et al. (1993)	FIM+FAM reliability.	Correlation; Rasch analysis.	*Interrater agreement:* FIM: 88% (81% admission-only). FAM: 67% (55% admission-only).	DOUBTFUL
Reliability	Law et al. (2009)	UK FIM+FAM EADL: accuracy; interrater and test-retest reliability for individuals/teams	Weighted Cohen's kappa.	*Agreement between raters and expert-rated scores:* Individual: k_w=.88-.97 (mean: .93). Team: k_w=.93-1.00 (mean: .96). Teams more accurate for all items except Housework. *Good-to-excellent interrater agreement:* Individual: k_w=.68-.92 (mean: .80). Team: k_w=.89-.99 (mean: .90). Teams more accurate for all items except Housework. *Excellent test-retest reliability:* Individual: k_w=.92-1.00 (mean .93) Team: k_w=.89-.99 (mean: .97). *Ambiguous vignettes*: excellent team/individual intrarater reliability/accuracy; excellent team interrater reliability; good individual interrater reliability.	VERY GOOD
Reliability	McPherson et al. (1996)	FIM+FAM interrater reliability.	Wilcoxon signed-rank test; unweighted kappa.	23 items >70%; 6 items 60-70%; 1 item (Adjustment to Limitations) <60%. Kappa = .50-.95 (good) for 29 items; for 14, kappa ≥.75 (12/14 Motor items, plus Memory and Comprehension). Poorer agreement for cognitive, communication and behavioural items.	DOUBTFUL

Psychometric characteristics evaluated	Study	Specific area of investigation	Statistical methodology	Key results relevant to FIM+FAM	COSMIN rating
Reliability	Turner-Stokes at al. (1999)	Team and individual interrater reliability of US and UK FIM+FAM.	T-test; chi-square; Cohen's kappa.	*Agreement between raters and expert-rated scores:* US FIM+FAM: individual (75%); team (84%). UK FIM+FAM: individual (77%); team (87%). Significantly higher team accuracy than individuals for US (p<.001) and UK (p<.01) versions. Percentage accuracy for ten most troublesome items higher in UK FIM+FAM than US for individual (p<.0001) but not team scores. *Interrater reliability:* 10 most troublesome items on UK FIM+FAM: k≥0.65 (very good) for individuals/teams.	DOUBTFUL
Construct validity	Austin et al. (2018)	External responsiveness compared to other measures.	Spearman's correlation.	Moderate-to-strong negative correlations with Neurological Impairment Set scores and change in FIM+FAM total (rho=-.74; p<.01), Motor (rho=-.74; p<.01) and Cognitive (rho=-.65, p<.01).	ADEQUATE
Construct validity	Balasch i Bernat et al. (2015)	FIM+FAM and FIM ability to discriminate between clinical disability categories.	Binary logistic regression.	*FIM cut-offs by disability severity:* Severe disability: 70.6 (95% CI: 66.7-75.2) Moderate disability: 38.3 (95% CI: 34.1-42.3) *FIM+FAM cut-offs by severity:* Severe disability: 116.1 (95% CI: 110.3-122.7) Moderate disability: 66.0 (95% CI: 59.2-72.3)	VERY GOOD
Construct validity	Foy and Somers (2013)	FIM+FAM ability to discriminate between TBI and non-TBI groups.	Independent samples t-tests.	No difference in Motor or Cognitive improvement between TBI/non-TBI groups during rehabilitation process (Cognitive: t(104)=-1.220, p<.225; Motor: t(104)=-.493, p=.623).	VERY GOOD
Construct validity	Gunn et al. (2018)	UK FIM+FAM factor structure in focal and diffuse ABI.	EFA; CFA.	General factor explained 75% variance (focal); 80% (diffuse). Focal: motor, psychosocial and communication factors explained 7%, 12% and 7% variance respectively; for diffuse, 3%, 10% and 6%.	DOUBTFUL

Psychometric characteristics evaluated	**Study**	**Specific area of investigation**	**Statistical methodology**	**Key results relevant to FIM+FAM**	**COSMIN rating**
Construct validity	Hall et al. (1993)	Criterion validity (against FIM and DRS).	Correlation.	FIM+FAM Motor correlations (p<.05): DRS (r=.68); GCS (r=.17), coma duration (r=.24); PTA duration (r=.44), trauma score (r=.19); LCFS (r=.47). FIM+FAM Cognitive correlations (p<.05): DRS (r=.75); GCS (r=.24), PTA duration (r=.45), trauma score (r=.19); LCFS (r=.63).	VERY GOOD
Construct validity	Hobart et al. (2001)	Comparability of responsiveness between measures.	Measures of disability.	*Responsiveness:* BI, FIM and FIM+FAM measures of global/motor disability similar.	VERY GOOD
Construct validity	McPherson and Pentland (1997)	Sensitivity of the FIM+FAM, FIM and OPCS Scales of Disability to functional impairment post-ABI against the BI.	Spearman ranked correlations.	*% gaining maximal scores:* BI: 69% OPCS: 7% FIM: 4% FIM+FAM: 2% *FIM+FAM correlations* (p<.001): Barthel Index: .53 OPCS: .82 FIM: .96	ADEQUATE
Construct validity	Nayar et al. (2016)	Differences in UK FIM+FAM outcome scores between left- and right-sided stroke.	Paired and non-paired t-tests; Mann-Whitney tests; Wilcoxon signed rank test.	Total scores did not significantly differ between right- and left-sided stroke, but left-sided stroke showed higher motor (p<.001) and lower cognitive scores (p<.001).	VERY GOOD
Construct validity	Turner-Stokes et al. (2009)	Comparability of internal responsiveness of FIM+FAM, BI and GAS.	Spearman's rho.	*Correlations baseline-discharge:* FIM+FAM and BI: rho=.84, p<.001) FIM+FAM and GAS: rho=.41-.49 *Personal goals:* 47% (315) mapped onto FIM; 62% (413) onto FIM+FAM.	VERY GOOD

Psychometric characteristics evaluated	**Study**	**Specific area of investigation**	**Statistical methodology**	**Key results relevant to FIM+FAM**	**COSMIN rating**
Construct validity	Wilson et al. (2009)	FIM+FAM ability to discriminate between TBI, cerebrovascular accident and other ABI/neurodegenerative diseases.	F tests	*Between-group differences:* no significant motor (p=.213), cognitive (p=.735) or total (p=.807) change between aetiological groups.	DOUBTFUL
Responsiveness	Austin et al. (2018)	Internal responsiveness; external responsiveness for UK FIM+FAM.	Wilcoxon signed-rank tests; effect size indices (Cohen's d, SRM, non-parametric effect sizes).	*Internal responsiveness (good):* significant admission-to-discharge changes: Motor (Cohen's *d*=.54), Cognitive (Cohen's *d*=.42) and total FIM+FAM (Cohen's *d*=.54) (p<.001 for all; large effects).	ADEQUATE
Responsiveness	Bajo et al. (1999)	Responsiveness; ceiling effects.	Wilcoxon tests.	*Significant improvements:* FAM (z=-2.7, p=.007, two-tailed). Communication subscale (z=-.28, p=.005, two-tailed) Psychological adjustment subscale (z=-.2.2, p=.025) Cognitive function (z=-3.4, p=.001) Not for FIM, self-care and mobility subscales *Ceiling effects:* self-care (76% at ceiling), mobility (79%)	DOUBTFUL
Responsiveness	Hobart et al. (2001)	Responsiveness.	Measures of disability.	*Responsiveness:* BI, FIM and FIM+FAM measures of global/motor disability similar.	VERY GOOD
Responsiveness	Nayar et al. (2016)	Differences in UK FIM+FAM outcome scores between admission and discharge.	Paired and non-paired t-tests; Mann-Whitney tests; Wilcoxon signed rank test.	All FIM+FAM subscales showed significant improvement between admission and discharge (p<.0001).	VERY GOOD

Psychometric characteristics evaluated	Study	Specific area of investigation	Statistical methodology	Key results relevant to FIM+FAM	COSMIN rating
Responsiveness	Turner-Stokes et al. (2009)	Internal responsiveness of FIM+FAM, BI and GAS.	Effect size (mean change); SRM; Wilcoxon z values.	*Change baseline-discharge:* Motor FIM+FAM: large effect: 1.0; Wilcoxon z: -10.8, p<.001; SRM: 1.53. Cognitive FIM+FAM: medium effect: 0.36; Wilcoxon z: -7.9, p<.001; SRM: 0.75. Total FIM+FAM: large effect size: 0.88; Wilcoxon z: -10.8, p<.001; SRM: 1.61. *Correlations baseline-discharge:* FIM+FAM and BI: rho=.84, p<.001) FIM+FAM and GAS: rho=.41-.49 *Personal goals:* 47% (315) mapped onto FIM; 62% (413) onto FIM+FAM.	VERY GOOD
Responsiveness	van Baalen et al. (2006)	Change sensitivity of FIM+FAM at discharge and one year post-injury.	SWK; ICC; SEM; SDD.	*FIM:* - Excellent SWK (discharge: .80; follow-up, .75). - Excellent ICC (discharge: .92; follow-up, .75). - Relatively small SEM (discharge: 6.17; follow-up: 3.22) and SDD (follow-up only: 8.92). *FAM:* - Excellent SWK (discharge: .69, follow-up .95). - Excellent ICC (discharge: .70, follow-up .95). - Relatively small SEM (discharge: 4.94, follow-up 1.32) and SDD (follow-up only: 3.66).	VERY GOOD
Responsiveness	Wilson et al. (2009)	Change sensitivity of UK FIM+FAM.	F tests	*Admission-discharge mean change scores:* (p<.001) Motor change: 12 Cognitive change: 7.3 Total FIM+FAM change: 19.3 *Between-group differences:* no significant motor (p=.213), cognitive (p=.735) or total (p=.807) change between aetiological groups. *Clinically meaningful effect*: Motor subscale (0.75); Cognitive subscale (0.52).	DOUBTFUL

Psychometric characteristics evaluated	Study	Specific area of investigation	Statistical methodology	Key results relevant to FIM+FAM	COSMIN rating
Predictive validity	Foy and Somers (2013)	Predictive validity of admission FIM+FAM scores on discharge scores.	Multiple regression; independent samples t-tests.	FIM+FAM Motor/Cognitive subscale admission scores predicted 80% variance in total discharge score (Motor: β=.80, T=10.09, p<.0005; Cognitive: β=1.03, T=8.61, p<.0005).	Not assessed by COSMIN
Predictive validity	Grauwmeijer et al. (2012)	Predictive validity of FIM and FAM in return to employment 3 years post-injury.	Longitudinal univariable/ multivariable regression; ROC analysis.	*Employed persons at 3 years:* higher acute discharge FIM and FAM (p<.001), current FIM (p=.002) and FAM (p=.001) than unemployed. *Regression:* Higher FAM predicted better employment likelihood (adjusted OR 0.92); p<.002). *FAM cut-off for unemployment risk at 3 years*: ≤65 (OR 6.9).	Not assessed by COSMIN
Predictive validity	Grauwmeijer et al. (2017)	Predictive validity of FIM and FAM in return to employment 10 years post-injury.	Longitudinal multivariable regression; Chi-square/exact tests; independent t-tests.	*Employed persons at 10 years:* higher acute discharge FIM (p<.016) and FAM (p<.023) than unemployed. *Regression:* Higher FAM predicted better employment likelihood (OR 1.05, p=.001).	Not assessed by COSMIN
Predictive validity	Grauwmeijer et al. (2014)	FIM+FAM predictive validity in HRQOL 3 years post-injury.	Linear mixed modelling.	*Univariable modelling:* FIM (β=.72, p<.001) and FAM (β=.58, p<.001) predicted physical HRQOL. *Multivariable modelling:* only FIM significant (β = .60, p < .001).	Not assessed by COSMIN
Predictive validity	Pietrapiana et al. (2005)	Examine predictive validity in safe return to driving after severe TBI.	Pearson correlation; chi-square; univariate ANOVA; hierarchical multiple regression.	No significant difference in FIM+FAM transfer/locomotion scores between those who did/did not return to driving. No significant correlation between any FIM+FAM variable and number of accidents/violations post-TBI. FIM+FAM not a predictor of return to driving after TBI.	Not assessed by COSMIN
Predictive validity	Valk-Kleibeuker et al. (2014)	Predictive validity of FIM and FAM in mood.	Univariable analyses; multivariable mixed model.	*Univariable analyses:* FIM (β=-0.22, p<.001) and FAM (β=-0.29, p<.001) predicted mood. *Multivariable analyses:* FAM still predictor (β=-0.28, p<.001); FIM no longer significant (p=.190).	Not assessed by COSMIN

Psychometric characteristics evaluated	Study	Specific area of investigation	Statistical methodology	Key results relevant to FIM+FAM	COSMIN rating
Abbreviations: ABI: acquired brain injury; ANOVA: analysis of variance; BI: Barthel Index; CFA: confirmatory factor analysis; CI: confidence interval; DRS: Disability Rating Scale; EADL: Extended Activities of Daily Living; EFA: exploratory factor analysis; FIM: Functional Independent Measure; FIM+FAM: Functional Independence Measure and Functional Assessment Measure; GCS: Glasgow Coma Scale; HRQOL: health-related quality of life; ICC: intraclass correlation coefficient; LCFS: (Rancho Los Amigos) Levels of Cognitive Functioning Scale; OPCS: Office of Population Census and Surveys; OR: odds ratio; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PCA: principal components analysis; PTA = post-traumatic amnesia; ROC: receiver operating characteristics; SDD: smallest detectable difference; SEM: standard error of measurement; SRM: standardised response mean; SWK: square weighted kappa; TBI: traumatic brain injury.					

Appendix I: Sample characteristics of included studies

Study	Sample size	Sample injury characteristics	Age – mean years (SD)	Sex (% female)	Sampling strategy
Alcott et al. (1997)	41 multidisciplinary healthcare professionals.	N/A	Not reported	Not reported	Recruited from two UK rehabilitation units.
Austin et al. (2018)	72 children/young people.	ABI.	13.4 (2.7)	Not reported	UK rehabilitation unit for children/young people.
Bajo et al. (1999)	38 participants.	ABI.	44 (range: 22-65)	21%	Unit specialising in cognitive and behavioural rehabilitation post-ABI.
Balasch i Bernat et al. (2015)	106 adults with stroke.	Ischaemic/haemorrhagic stroke.	Median years: 69 (85.9% aged 65-75)	45%	Spanish rehabilitation facility (stroke pathway).
Donaghy and Wass (1998)	MDT members.	Complex ABI.	38.2 (13.7)	25%	Patients admitted to Canadian rehabilitation unit.
Foy and Somers (2013)	106 young adults.	Moderate to severe ABI.	TBI: 19.7 (5.1) Non-TBI: 18.4 (4.3)	TBI: 17% Non-TBI: 48%	Consecutive admissions to UK rehabilitation unit.
*Grauwmeijer et al. (2012)	94 participants.	Moderate to severe non-penetrating TBI with GCS score 3-12; aged 16-67 years.	*Employed:* 29.5 (10.7) *Unemployed:* 37.9 (14.2)	*Employed:* 28% *Unemployed:* 32%	Consecutive patients admitted to 3 rehabilitation units in the Netherlands.
*Grauwmeijer et al. (2017)	48 participants.	Moderate to severe non-penetrating TBI with GCS score 3-12; aged 16-67	34.3 (12.7) (*employed:* 32.7 (11.5); *unemployed:*	33% (*employed:* 27%; *unemployed:* 41%).	Consecutive patients admitted to 3 rehabilitation

Study	Sample size	Sample injury characteristics	Age – mean years (SD)	Sex (% female)	Sampling strategy
		years.	36.2 (14.0)) *Attrited:* 30.2 (11.0)	*Lost to follow-up:* 23%	units in the Netherlands.
*Grauwmeijer et al. (2014)	97 participants (66 completed follow-up).	Moderate to severe non-penetrating TBI with GCS score 3-12; aged 16-67 years.	32.8 (13)	28%	Consecutive patients admitted to 3 rehabilitation units in the Netherlands.
Gunn et al. (2018)	835 FIM+FAM assessments; 447 participants.	Complex ABI.	47.6 (14.8)	35%	All admissions to a UK rehabilitation unit, unless discharged within a week.
Hall et al. (1993)	20 MDT raters. 311 FIM cases. 271 FAM cases.	MDT professionals. Patients with TBI.	Patients: 34.5 (16.0).	Patients: 22%	Admissions to any rehabilitation unit registered with UK national database.
Hall et al. (1996)	FIM cases: 133. FIM+FAM cases: 80.	TBI patients capable of 3 hours' rehabilitation daily.	Not specified; subset of different study.	Not specified; subset of different study.	Admissions to any rehabilitation unit registered with US national database.
Hawley et al. (1999)	2268 FIM+FAM assessments; 965 participants.	TBI.	35.6 (14.6)	24%	Admission to any of 11 UK rehabilitation units.
Hobart et al. (2001)	149 inpatients.	Stroke, other ABI, multiple sclerosis or other neurological impairment.	46.2 (14.8)	54%	Patients admitted to one of two UK rehabilitation units.
Law et al. (2009)	12 participants split into 4 teams.	MDT rehabilitation professionals.	*Professional experience:* 8.3 years,	Not reported	Volunteers from two UK rehabilitation units.

Study	Sample size	Sample injury characteristics	Age – mean years (SD)	Sex (% female)	Sampling strategy
	Scoring accuracy: 6000 individual and 2000 team ratings.		range 2-18 *FIM+FAM experience:* 31.9 months, range 2-156		
Linn et al. (1999)	376 participants.	Stroke with unilateral dysfunction.	*Left-sided dysfunction:* 67.5 (10.6) *Right-sided dysfunction:* 66.6 (11.6)	*Left-sided dysfunction:* 50.3% *Right-sided dysfunction:* 47.1%	Patients admitted to a Canadian rehabilitation unit.
McPherson et al. (1997)	54 participants.	TBI.	36 (SD not noted)	24%	Patients admitted to a UK unit, living within one hour of Edinburgh.
McPherson et al. (1996)	30 inpatients. 2 raters.	ABI via TBI (43%), haemorrhage (27%), spinal surgery (13%) or other neurological condition (17%).	48.4 (range: 17-88)	Not noted	Patients admitted to a UK rehabilitation unit in the UK.
Nayar et al. (2016)	1539 participants (left-sided stroke: 588; right-sided: 566).	Patients with right- or left-sided stroke (excluding sub-arachnoid haemorrhage).	*Left-sided:* 58.7 (16.4) *Right-sided:* 55.7 (15.6)	*Left-sided:* 39%. *Right-sided:* 41%	Admissions to any of 60+ UK rehabilitation units.

Study	Sample size	Sample injury characteristics	Age – mean years (SD)	Sex (% female)	Sampling strategy
Pietrapiana et al. (2005)	66 pairs (TBI patient, primary caregiver).	Severe TBI (GCS ≤8) a minimum of one year prior to study.	*Patients:* 34.4 (9.41) *Caregivers*: 40.4 (13.9)	*Patients:* 18% *Caregivers:* 62%	Patients who had completed a rehabilitation programme at an Italian unit.
Turner-Stokes et al. (1999)	*US FIM+FAM:* 37 individuals (3330 item ratings), 11 teams (990 ratings). *UK FIM+FAM:* 28 individuals (2520 ratings), 9 teams (810 ratings).	N/A – interdisciplinary rehabilitation healthcare professionals.	*US FIM+FAM* experience: 0-54 months (mean 19. *UK FIM+FAM* experience: 0-60 months (mean 24)	Not noted	Volunteers from eight UK centres using the FIM+FAM.
Turner-Stokes & Siegert (2013)	459 participants.	84% ABI (67% vascular; 17% TBI; 16% other ABI); 8% spinal injury; 8% other neurological disorder.	44.5 (14.3)	43%	Patients admitted to a UK tertiary rehabilitation unit.
Turner-Stokes et al. (2009)	164 participants.	66% ABI by stroke; 18% TBI; 16% other ABI.	44.8 (14.4)	38%	Patients admitted to a UK tertiary rehabilitation unit.
Wilson et al. (2009)	65 participants.	Cerebrovascular accident, TBI, other ABI, spinal cord injury, multiple sclerosis.	39.2 (14.7)	Not reported	Patients referred to a UK rehabilitation outpatient clinic.
Valk-Kleibeuker et al. (2014)	98 participants.	Moderate or severe TBI, aged 16-67, acute admission GCS of 3-12.	33 (12.9)	28%	Patients admitted to any of 3 Dutch acute hospitals.

Study	Sample size	Sample injury characteristics	Age – mean years (SD)	Sex (% female)	Sampling strategy
van Baalen et al. (2006)	25 participants (14 by one-year follow-up).	TBI, aged 18-65 years, admission GCS of ≤14.	*Initial discharge:* 35.3 (12.8) *Follow-up:* not reported	*Initial discharge:* 32% *Follow-up:* not reported	Consecutive admissions to a rehabilitation unit in the Netherlands.
Abbreviations: ABI = acquired brain injury; FIM+FAM = Functional Independence Measure and Functional Assessment Measure; GCS = Glasgow Coma Score; MDT: multidisciplinary team; TBI = traumatic brain injury.					

Appendix J: Guidelines for journal (empirical paper submission)*

Neuropsychological Rehabilitation

Aims and scope

(https://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=pnrh20)

Neuropsychological Rehabilitation publishes human experimental and clinical research related to rehabilitation, recovery of function, and brain plasticity. The journal is aimed at clinicians who wish to inform their practice in the light of the latest scientific research; at researchers in neurorehabilitation; and finally at researchers in cognitive neuroscience and related fields interested in the mechanisms of recovery and rehabilitation. Papers on neuropsychological assessment will be considered, and special topic reviews (2500-5000 words) addressing specific key questions in rehabilitation, recovery and brain plasticity will also be welcomed. The latter will enter a fast-track refereeing process.

Peer Review: All submitted manuscripts are subject to initial appraisal by the Editor, and, if found suitable for further consideration, to peer review by independent, anonymous expert referees. All peer review is single blind and submission is online via ScholarOne Manuscripts.

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For those interested in any aspect of remediation in brain-damaged patients, this journal contains much essential reading and is highly recommended..... the articles are aimed primarily at those with a background in psychological investigation. However, those from related professions such as speech therapy should find most of the articles accessible.
Alan Parkin, The Times Higher Educational Supplement

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(https://www.tandfonline.com/action/authorSubmission?journalCode=pnrh20&page=instructions)

Thank you for choosing to submit your paper to us. These instructions will ensure we have everything required so your paper can move through peer review, production and publication smoothly. Please take the time to read and follow them as closely as possible, as doing so will ensure your paper matches the journal's requirements. For general guidance on the publication process at Taylor & Francis please visit our Author Services website.

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This title utilises format-free submission. Authors may submit their paper in any scholarly format or layout. References can be in any style or format, so long as a consistent scholarly citation format is applied. For more detail see the format-free submission section below.

About the Journal

Neuropsychological Rehabilitation is an international, peer-reviewed journal, publishing high-quality, original research. Please see the journal's Aims & Scope for information about its focus and peer-review policy. Please

Appendix J (continued) Guidelines for journal (empirical paper submission)*

Neuropsychological Rehabilitation

note that this journal only publishes manuscripts in English. This journal accepts the following article types: original (regular) articles, scholarly reviews, and book reviews.

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Your paper should be compiled in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list).

Word Limits

Please include a word count for your paper. There are no word limits for papers in this journal.

Format-Free Submission

Authors may submit their paper in any scholarly format or layout. Manuscripts may be supplied as single or multiple files. These can be Word, rich text format (rtf), open document format (odt), or PDF files. Figures and tables can be placed within the text or submitted as separate documents. Figures should be of sufficient resolution to enable refereeing.

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- Spelling can be US or UK English so long as usage is consistent.

Note that, regardless of the file format of the original submission, an editable version of the article must be supplied at the revision stage.

Appendix K: Chronology of the research process*[6]

October 2017 – November 2017

Consultation with academic supervisor regarding idea for study of cognitive assessment in people with acquired brain injury, comparing measures using process-based methodologies against standardised battery approaches.

January 2018 – March 2018

Proposal development via meetings with academic supervisor and Head of Neuropsychology at hospital for acquired brain injury rehabilitation.

May 2018

Initial research proposal, Service User Reference Group review and research costs form submission.

Good Clinical Practice and Consent with Vulnerable Adults training.

June 2018

Internal meeting for peer review of research proposal.

Submission for ethical approval via Integrated Research Application System (IRAS).

July 2018

Attended Clinical Neuropsychology departmental meeting at acquired brain injury hospital. Concerns raised by clinicians that hospital admissions policies will preclude admission of many patients with sufficient cognitive function to complete the proposed protocol, and certainly will not achieve adequate power for analysis. On discussing again with the Head of Neuropsychology, he agreed. Mutual agreement reached to pause this project temporarily, in favour of another project for the thesis.

IRAS application withdrawn with explanation to HRA and to local Research and Development office.

[6] For reflection on research process, see Appendix V.

Production of alternative research proposal, to analyse roles of social and therapeutic engagement in rehabilitation.

Completion and submission of necessary approvals form for Clinical Audit and Effectiveness Department, South Warwickshire NHS Foundation Trust. Approval received (Appendix Q).

August 2018

Completion and submission of necessary approvals form for University of Leicester Ethics Review.

September 2018

Approval received from University of Leicester (Appendix P).

October 2018

Met with Assistant Psychologists to review existing database and determine which components are required for the study. Discuss data collation and anonymisation, seeking advice from Research and Development on appropriate anonymisation processes for moving data off-site for analysis on university software.

Preliminary data analysis to provide outcomes by Clinical Audit and Effectiveness deadline (20/10/18).

Discussed literature review topic with supervisor. Settled on evaluation of psychometric properties of the Functional Independence Measure and Functional Assessment Measure.

November 2017 – January 2018

Literature review development and write-up.

December 2018

Full/formal data analysis.

January 2019

Submit literature review.

Submission of literature review to *Disability and Rehabilitation* (for guidelines, see Appendix A).

February 2019 – May 2019

Data analysis and write-up.

Identification of journal for submission of experimental paper (*Neuropsychological Rehabilitation*, for guidelines, see Appendix J).

May 2019

Thesis submission.

July 2019 – September 2019

Planned dissemination including summary report to rehabilitation hospital, development of empirical paper for journal submission and identification of appropriate conferences to present findings.

Appendix L: Epistemology*

The researcher adopted a positivist epistemological stance, i.e. taking the position that the constructs of physical, cognitive and psychosocial difficulties post-ABI are objective entities that can be quantified using validated measures (Breen & Darlaston-Jones, 2009). The empirical study design reflected this, relying on tools and measures to quantify characteristics in a manner suitable for statistical analyses, which were considered evidence for or against hypotheses. The researcher and data are assumed to be unrelated (and in fact minimising research influence over the data is preferred), which meant that use of retrospective data was appropriate to a positivist position. The researcher generally finds a critical realist stance more comfortable and produces a broader/more flexible focus than positivist approaches, as it allows for consideration that one's understanding of others' realities is filtered through one's own experiences/beliefs and through mutual understandings and interpretations of language, and so we can only access interpreted accounts of others' experience rather than full understanding (Braun & Clarke, 2013; Breen & Darlaston-Jones, 2009; Sims-Schouten et al., 2007; Willig, 1999). However, since the literature review comprised synthesis of data gathered via positivist epistemologies and the empirical project likewise built on positivist research using a database of previously-gathered information, the positivist approach seemed the best fit for the subject matter.

The researcher's experience of working in an ABI rehabilitation setting informed the planning and conduct of the research. A significant motivator was an interest in developing more accurate predictive models of recovery, having worked with individuals with ABI and their families who generally hope to have more information about their future than is currently available. In this sense the wish for certainty from families and individuals may have further encouraged the researcher to seek a positivist position, in hopes of providing answers.

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Appendix M: Patient Categorisation Tool*

Patient Categorisation Tool **Patient Name:..............................** **ID Number (e.g hospital/NHS number) ....**

Complex disability management	Complex disability management eg ☐ Evaluation of low awareness state ☐ Neuro-palliative rehabilitation / end of life care	☐ Standard disability management eg set-up of care progamme, care booklet, carer training etc	☐ None required
Social / discharge planning	☐ Complex placement / housing /funding issues requiring extensive multi-agency negotiation	☐ Active discharge planning requiring liaison with community SW/DN/OT eg to arrange care package	☐ No major discharge issues, taken care of by family / allocated social worker
Family support	☐ Major family distress issues require frequent support or crisis intervention	☐ Routine family support needs (met by planned meetings)	☐ No significant family problems
Emotional load on staff	☐ Demanding situation requiring highly experienced staff / extra support for staff	☐ Somewhat challenging situation but manageable	☐ Minimal or no emotional load on staff

Vocational rehabilitation	Specialist vocational rehabilitation needs eg ☐ Multi-disciplinary vocational assessment ☐ Multi-agency support for return to work, retraining or work withdrawal ☐ Complex support in other roles (eg single-parenting)	Moderate vocational support, ☐ Work visits or employer liaison ☐ Support for other roles, eg home-maker / parenting	☐ Not of working age ☐ No significant needs for vocational support
Medico-legal issues	Complex medico-legal issues eg requiring interaction with legal system: ☐ Complex Best interests decisions ☐ Court of protection applications ☐ DoLs / PoVA applications ☐ Litigation issues ☐ Complex mental capacity / consent issues	Standard medico-legal issues eg ☐ Mental capacity evaluation ☐ Standard consent / best interests decisions ☐ LPoA, advance care planning	☐ No significant medico-legal issues
Specialist equipment / facilities	Highly specialist equipment /facilities required eg ☐ Bespoke Assistive technology ☐ Highly specialist seating/wheelchair needs ☐ Bespoke orthotics ☐ Electronic assistive technology ☐ Assisted ventilation	Moderate specialist equipment needs eg ☐ Adapted Wheelchair / seating ☐ Electric standing frame ☐ Treadmill/harness training ☐ Assisted cycling (eg motor-med) ☐ Splinting / casting	☐ No equipment needs ☐ Basic off the shelf equipment only ☐ Standard exercise facilities, eg plinth, bike tilt-table, parallel bars

Service level required	**Category** ***Clinical Impression***	**Expected duration of admission**	**Funding Source** (to be entered in Episode section – Commissioning & Referral of UKROC software)	**Assessor (Print Name)**
Clinical Impression ☐ Level 1 ☐ Level 2a ☐ Level 2b ☐ Level 3	☐ A ☐ B ☐ C ☐ D ☐ Not applicable	☐ Long stay (5-6 months) ☐ Medium (3-4 months) ☐ Short (6-8 weeks) ☐ Assessment / rapid intervention (2-4 wks) ☐ Not applicable (slow stream or not for rehab)	☐ Clinical Commissioning Group (CCG) ☐ NHS Commissioning Board (NHSCB) ☐ NHS outside England ☐ Social Services ☐ Private	**Signed by assessor** --
☐ Slow stream / Specialist nursing home ☐ Community rehab ☐ Not for rehab **Has onward referral been made?** ☐ No ☐ Yes (where to)________		**Reasoning / Alternative recommendations:**	**Purchasing type** ☐ Contract ☐ Other (e.g spot purchasing)	**Date Completed** --

UKROC Patient Categorisation Tool Version 2 – 15.03.13 Page 2 of 2

Appendix M (continued): Patient Categorisation Tool*

Patient Categorisation Tool **Patient Name:..............................** **ID Number (e.g hospital/NHS number) ....**

Complex disability management	Complex disability management eg ☐ Evaluation of low awareness state ☐ Neuro-palliative rehabilitation / end of life care	☐ Standard disability management eg set-up of care progamme, care booklet, carer training etc	☐ None required
Social / discharge planning	☐ Complex placement / housing /funding issues requiring extensive multi-agency negotiation	☐ Active discharge planning requiring liaison with community SW/DN/OT eg to arrange care package	☐ No major discharge issues, taken care of by family / allocated social worker
Family support	☐ Major family distress issues require frequent support or crisis intervention	☐ Routine family support needs (met by planned meetings)	☐ No significant family problems
Emotional load on staff	☐ Demanding situation requiring highly experienced staff / extra support for staff	☐ Somewhat challenging situation but manageable	☐ Minimal or no emotional load on staff

Vocational rehabilitation	Specialist vocational rehabilitation needs eg ☐ Multi-disciplinary vocational assessment ☐ Multi-agency support for return to work, retraining or work withdrawal ☐ Complex support in other roles (eg single-parenting)	Moderate vocational support, ☐ Work visits or employer liaison ☐ Support for other roles, eg home-maker / parenting	☐ Not of working age ☐ No significant needs for vocational support
Medico-legal issues	Complex medico-legal issues eg requiring interaction with legal system: ☐ Complex Best interests decisions ☐ Court of protection applications ☐ DoLs / PoVA applications ☐ Litigation issues ☐ Complex mental capacity / consent issues	Standard medico-legal issues eg ☐ Mental capacity evaluation ☐ Standard consent / best interests decisions ☐ LPoA, advance care planning	☐ No significant medico-legal issues
Specialist equipment / facilities	Highly specialist equipment /facilities required eg ☐ Bespoke Assistive technology ☐ Highly specialist seating/wheelchair needs ☐ Bespoke orthotics ☐ Electronic assistive technology ☐ Assisted ventilation	Moderate specialist equipment needs eg ☐ Adapted Wheelchair / seating ☐ Electric standing frame ☐ Treadmill/harness training ☐ Assisted cycling (eg motor-med) ☐ Splinting / casting	☐ No equipment needs ☐ Basic off the shelf equipment only ☐ Standard exercise facilities, eg plinth, bike tilt-table, parallel bars

Service level required	**Category** ***Clinical Impression***	**Expected duration of admission**	**Funding Source** (to be entered in Episode section – Commissioning & Referral of UKROC software)	**Assessor (Print Name)**
Clinical Impression ☐ Level 1 ☐ Level 2a ☐ Level 2b ☐ Level 3	☐ A ☐ B ☐ C ☐ D ☐ Not applicable	☐ Long stay (5-6 months) ☐ Medium (3-4 months) ☐ Short (6-8 weeks) ☐ Assessment / rapid intervention (2-4 wks) ☐ Not applicable (slow stream or not for rehab)	☐ Clinical Commissioning Group (CCG) ☐ NHS Commissioning Board (NHSCB) ☐ NHS outside England ☐ Social Services ☐ Private	**Signed by assessor** ---------------------------------------
☐ Slow stream / Specialist nursing home ☐ Community rehab ☐ Not for rehab **Has onward referral been made?** ☐ No ☐ Yes (where to)		**Reasoning / Alternative recommendations:**	**Purchasing type** ☐ Contract ☐ Other (e.g spot purchasing)	**Date Completed** ---------------------------------------

UKROC Patient Categorisation Tool Version 2 – 15.03.13 Page 2 of 2

Reference

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Appendix N: Measures used

Due to the literature review comprising a full FIM+FAM summary, only relevant additional considerations are presented here to avoid replication.[7] The FIM+FAM possesses generally positive psychometric properties, including no floor effect even in severely-impaired ABI populations (summary: Gunn & Burgess, submitted), but also possesses limitations. For example, test efficiency and interrater reliability are good but not excellent (Hall et al., 1996; Hall et al., 1993; Nayar et al., 2016). The subscales may also be of questionable relevance; while one study (Hawley et al., 1999) found support for the manualised Cognitive and Motor subscales, others identified three- (Nayar et al., 2016), four- (Hall et al., 2001) and bi-factor models (Gunn et al., 2018) which better fitted the data. For this reason total scores were included as an outcome measure alongside the Motor/Cognitive subscales, and conclusions from subscale analysis, while informative, should be treated with caution. The Cognitive subscale (which includes SI) is particularly difficult to score due to item abstractness/poor “imageability”, reducing outcome reliability (Alcott et al., 1997; Hall, 1992; McPherson et al., 1996; Turner-Stokes et al., 1999). There may also be an effect of sample characteristics on FIM+FAM validity; while scores of 2-6 contribute significantly to overall outcomes, extreme scores of 1/7 (i.e. very high or low independence) do not. As the sample comprised highly-complex patients with severe ABI, many scored 1 on SI or other items contributing to Motor/Cognitive outcomes, potentially reducing effectiveness of the measure (Gurka et al., 1999).

The PCAT is little-researched despite wide UK usage across rehabilitation hospitals, but inferences can be made from the two existing studies. While only reasonable sensitivity/specificity (76%/75%) was identified by (Turner-Stokes et al., 2019) and conflicting factor analytic interpretations are offered by Turner-Stokes et al. (two-factor model) and (Siegert et al., 2018) (three-factor), these are not necessarily problematic for this study which uses three individual items which did not cross-load between factors

[7] When rewriting the paper for journal submission, further detail will be included in the Method.

(while other items did). Given use of PCAT scores in this study to test SI convergent validity, convergent/divergent validity with other measures are of more interest. Turner-Stokes et al. identified a large-effect inverse correlation (r_s=-.56) between PCAT and FIM+FAM Total scores, predictably as high FIM+FAM scores indicate greater independence while higher PCAT scores indicate greater need. The PCAT also discriminates well between subjective clinician-categorised levels of complexity ($p<.001$), although this validity of this is highly questionable (e.g. clinicians may be using PCAT criteria to make their decision). Additionally, while PCAT scores were correlated against other UK Rehabilitation Outcomes Collaborative scores of dependency/complexity, these measures are all generated by the same group and share similar foci/criteria (Plantinga et al., 2006; Turner-Stokes et al., 1998; Turner-Stokes et al., 2012), so correlations may be somewhat artificial/inflated. This may somewhat explain the low correlations with SI.

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Appendix O: Potential confounds

Multiple factors were excluded as potential predictive variables, which was necessary due to the reduction in statistical power which would be associated with including all previously-reported predictors of ABI recovery outcomes. Variables were therefore excluded either on the grounds of poor data recording (too much missing data), relevant data not being available, or the evidence base comprising a poor argument for inclusion.

In terms of demographics, race/ethnicity were excluded as potential predictors due to the overwhelmingly white European sample, and because including small cell sizes comprising minorities sample subsets of other racial/ethnic backgrounds could have compromised anonymity for individuals (see Appendix R). Comorbidities had been very rarely recorded, so were also not included due to the amount of missing data, despite evidence that diabetes, cardiovascular conditions and prior ABI may predict outcomes (Hankey et al., 2007; Macciocchi et al., 1998; Weimar et al., 2002). Sex was excluded due to the extremely limited evidence of its relevance to rehabilitative success (e.g. Bonita & Beaglehole, 1988; Mizrahi et al., 2012), despite some evidence that males have better overall rehabilitation outcomes (Adams et al., 2004). Age was however included, as the majority of research shows age to be inversely correlated with improvement post-ABI (Balestreri et al., 2004; Dawson & Chipman, 1995; Gray & Burnham, 2000; Horn et al., 2015; Lehmann et al., 1975; Macciocchi et al, 1998; Ponsford et al., 1995; Rothweiler et al., 1998), although some studies found that age only influenced recovery in younger (Kelly et al., 2003) or older adults (Hankey et al., 2007; Ween et al., 1996), or that age predicted recovery of physical function but not cognitive/psychosocial skills (Nakayama et al., 1994; Wood & Rutterford, 2006). Others found age unrelated to recovery altogether (Bonita & Beaglehole, 1998; Hoofien et al., 2002; Tate et al., 2005).

Injury location was also excluded, as evidence linking injury location with rehabilitative outcomes is inconsistent (despite suggestions that right-hemisphere lesions may impair physical function recovery) (Alexander, 1994; Arboix et al., 2001; Ezzat Nazzal et al., 2009; Lehmann et al., 1975; Macciocchi et al., 1998; Ween et al., 1996). Injury type was included, however, as the evidence base that aetiology relates to outcomes was stronger (Dikmen et al., 1995; Hankey et al., 2007; Hoofien et al., 2002; Lehmann et al., 1975; Macciocchi et al., 1998) and this was replicated in this study's findings relating to cognitive rehabilitation.

Several factors were excluded on the basis that the hospital database typically does not record them. This was somewhat problematic as important contributors may have been neglected, but could not be addressed in the retrospective dataset. Time between injury and hospital admission has been shown to predict rehabilitation outcomes (Gray & Burnham, 2000) but these data were not routinely recorded, since the study took place in a post-acute inpatient rehabilitation service rather than acute hospital. Education and pre-injury employment status were likewise not recorded, despite evidence that they may contribute to rehabilitation outcomes (Dawson & Chipman, 1995; Fernandes et al., 2012; Lehmann et al., 1975; J. Ponsford et al., 2008; Tate et al., 2005). Finally, although injury severity may be associated with mortality over the short term (Bonita & Beaglehole, 1988), there were insufficient deaths to analyse mortality as an outcome measure.

A last consideration was the role of length of stay, which can predict clinical improvement (Alexander, 1994; Kelly et al., 2003; Macciocchi et al., 1998). It was used as a rehabilitation outcome in this study, and therefore not directly used as a predictor; however, it may potentially confound the role of individual therapy/group engagement, as those with a longer duration of stay are likely to receive more therapy. To address this concern, the individual therapy and group engagement variables were recalculated as weekly mean values rather than totals.

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Appendix P: Approval letter from University of Leicester Ethics Review*

UNIVERSITY OF LEICESTER

University Ethics Sub-Committee for Psychology

04/09/2018

Ethics Reference: [redacted]

TO:
Name of Researcher Applicant: [redacted]
Department: Psychology
Research Project Title: Sociotherapeutic engagement and neurobehavioural predictors of recovery following acquired brain injury

Dear [redacted],

RE: Ethics review of Research Study application

The University Ethics Sub-Committee for Psychology has reviewed and discussed the above application.

1. Ethical opinion

The Sub-Committee grants ethical approval to the above research project on the basis described in the application form and supporting documentation, subject to the conditions specified below.

2. Summary of ethics review discussion

The Committee noted the following issues:
All potential ethics issues covered.

3. General conditions of the ethical approval

The ethics approval is subject to the following general conditions being met prior to the start of the project:

As the Principal Investigator, you are expected to deliver the research project in accordance with the University's policies and procedures, which includes the University's Research Code of Conduct and the University's Research Ethics Policy.

If relevant, management permission or approval (gate keeper role) must be obtained from host organisation prior to the start of the study at the site concerned.

Appendix P (continued): Approval letter from University of Leicester Ethics Review*

University of Leicester — University Ethics Sub-Committee for Psychology

4. Reporting requirements after ethical approval

You are expected to notify the Sub-Committee about:

- Significant amendments to the project
- Serious breaches of the protocol
- Annual progress reports
- Notifying the end of the study

5. Use of application information

Details from your ethics application will be stored on the University Ethics Online System. With your permission, the Sub-Committee may wish to use parts of the application in an anonymised format for training or sharing best practice. Please let me know if you do not want the application details to be used in this manner.

Best wishes for the success of this research project.

Yours sincerely,

Prof. Panos Vostanis
Chair

Appendix Q: Approval email from South Warwickshire NHS Foundation Trust Clinical Audit and Effectiveness Department*

[redacted]

Mon 16/07/2018 11:22

Mark as unread

To: [redacted]

Cc:

• You replied on 11/10/2018 10:38.

Dear all,

This is to confirm that the above audit has been registered (**1746**) and is on the **2018-2019** audit programme.

The conclusions and actions will be reported to the monthly **Elective and CERU AOGG's.**

This audit is due to be completed (with completed action plan and actions) by **20th Oct 2018**

The responsibility for making sure this audit is completed and action plan implementation lies with the clinical lead, [redacted]

Financial/organisational responsibility for any actions arising will lie with the management lead [redacted]

The project lead who has the responsibility of undertaking the audit is [redacted]

[redacted] has been assigned to oversee this Clinical audit, if you have any queries, please contact them or if they are unavailable then contact the Clinical Audit and Effectiveness Department on ext. 4279.

Kind Regards,

[redacted]

Clinical Audit and Effectiveness Facilitator

[redacted]

Appendix R: Ethics and study development

I was fortunate to have prior experience of the ethics application process, which made it less daunting. Final project approval was relatively straightforward, requiring basic NHS audit and university form submissions, and the approval process was reasonably smooth. However, the overall process was far more complicated. I began with a different project, intending to evaluate the comparative predictive validity of process-based and standardised cognitive assessment following acquired brain injury. This built on a prior study finding that FIM+FAM-assessed elements of cognition such as language ability significantly predicted rehabilitation outcomes (Gunn & Burgess, submitted); I therefore wanted to use my thesis to evaluate cognitive predictors using specialised neuropsychological assessments, as the FIM+FAM is a relatively broad-brush measure.

I had discussed this with the hospital before beginning the DClinPsy, and had planned a draft protocol which I had shared with the Head of Neuropsychology. I therefore knew that the proposal would be accepted and achievable within the team. Unfortunately, having prepared the relevant documentation, gone through the university peer review process and submitted to IRAS, one of the clinical psychologists raised that the hospital admission criteria had changed. The hospital now admitted very few individuals capable of completing the planned lengthy cognitive assessments, due to a shift in focus towards specialising in prolonged disorders of consciousness. It was anticipated that perhaps 20 suitable participants would be admitted over the 12-14 months of collecting data (which would be extremely underpowered). We discussed this at length in a team meeting, and concluded that the idea was no longer practicable.

Upon consideration, I thought of a different way to explore predictors of acquired brain injury recovery. Gunn and Burgess (submitted) had also identified that the SI item was one of the most important predictors of Motor/Cognitive recovery and length of stay. I was fortunately aware of hospital resources, as it was part of my previous job to collate research data on inpatient assessment and progress, including the FIM+FAM. I therefore developed an alternative empirical study examining SI contributions to rehabilitation, using extensive data which were already available, and had been collected with the agreement that it could be used for research.

The main ethical complication was therefore appropriate use of this data. Although I was still employed by the hospital on the bank and involved in research, I asked the Assistant Psychologists who now ran the data input to extract and anonymise the information I needed (so that I would only see fully anonymised data). This took some time and I was very grateful for their help; I offered that once I had submitted my thesis, they could be involved in writing up the study for publication. They were happy with this and we agreed with the Head of Neuropsychology that they could allocate working time to collation/anonymisation of the data.

I sought advice from the Research and Development Team by phone regarding appropriate anonymisation of the database, and established that full anonymisation required there be no means to retrospectively identify participants. Fortunately this did not present any issues of risk/concern for individuals, as all progress-monitoring data were produced by the interdisciplinary team during team meetings so they were aware of issues. Therefore, the data were extracted and anonymised fully, and the anonymised data sent to me via secure NHS.net email, passworded for additional security. Finally, again to avoid rendering participants identifiable, I decided with the team to omit certain characteristics from analysis, e.g. non-white European participants comprised very small minorities in the dataset, so this characteristic was omitted.

Reference

Gunn, S., & Burgess, G. H. (submitted). Functional, cognitive, aetiological and demographic predictors of rehabilitation outcomes after severe acquired brain injury: A cohort study.

Appendix S: Methodological limitations

Further details are here presented on potential limitations noted in the empirical paper.

Sample

Any sample choice creates certain limitations; e.g. selecting a specific population by service (inpatient/outpatient/community) or aetiology limits findings to that population, while increasing confidence regarding applicability of findings within that population. In this study, all individuals with ABI were included without restricting to a specific aetiology. While this improves generalisability among inpatient rehabilitation populations (which are infrequently restricted to one aetiology), the mixed-ABI population also reduces the capacity to draw conclusions about specific aetiologies. Future research might address this (Appendix U). Additionally, it would be inadvisable to generalise findings to community/outpatient or even slow-stream inpatient rehabilitation environments, where physical and low-level cognitive difficulties such as memory/orientation are typically supplanted as the primary rehabilitative focus by more complex cognitive impairments, e.g. executive function difficulties (Gray et al., 1994; Kilgore, 1995; Powell, 1999; 2002). Finally, derivation of data from a single unit may reduce generalisability to other units (Jongbloed, 1986).

There were further sources of sampling bias. Although there was a wide range of ages, the distribution of sexes was uneven (62.8% male). While this could be considered representative of the generally-higher risk of ABI in males, particularly in certain aetiologies (e.g. TBI/stroke; Bruns & Hauser, 2003; Elkind & Sacco, 1998), it reduces generalisability to female populations given reported sex differences in rehabilitation outcomes (Adams et al., 2004) – although these differences are not identified in all studies (Bonita & Beaglehole, 1988; Mizrahi et al., 2012). There was further potential for bias in terms of race/ethnicity, since the vast majority of participants were white European. Studies have found that race/ethnicity influences post-ABI recovery; people of African/Hispanic/Asian descent appear to have poorer rehabilitation outcomes than those of European descent (Bhandari et al., 2005; Ottenbacher et al., 2008). This study's findings cannot therefore be generalised beyond white European populations.

Measures

Limitations of the FIM+FAM/PCAT are discussed in Appendix N. It should additionally be considered that only clinician-report was used, which neglects patient self-report and relative-reports. While this was for valid reasons relating to common post-ABI impairments to memory, insight and/or communication in participants, and relatives having low contact with their admitted relatives (and consequently potentially lacking information about their wellbeing/behaviour/function), not gathering information from individuals/relatives neglects complex experiences of social, emotional and personality changes from the person with ABI and those most familiar with them (Alexander, 1997; Jackson et al., 1992; Milders et al., 2003; Tate, 1999). Future studies should incorporate clinician-, self- and relative-report, although considering that complex multivariate models may be difficult to apply clinically (Gladman et al., 1992).

Design

While retrospective use of ten years' data enabled appropriately-powered analyses in a way which would be impossible for data collected during the DClinPsy, retrospective data use restricts methodological flexibility and prevents free choice of measures and methods/times of administration. Additionally, potentially important variables such as education, time between injury and admission, and premorbid employment status were absent from the database (see Appendix O); this could not be corrected due to the retrospective design. There is also a risk that data gathered retrospectively may carry greater levels of inaccuracy (Nayar et al., 2016). Prospective multicentre studies allow for addressing of all three difficulties (see Appendix U).

Findings from the data on behaviours of concern should be treated with particular caution for multiple reasons. They rely on inpatient ward recordings by staff with varied experience; quality, accuracy and consistency of recordings is therefore uncertain. The range of group and individual engagement data is small for these groups, with many patients receiving no (recorded) input; this may have affected the usefulness of these data for discriminating between groups. The behavioural data also report only on those selected for one-to-one observation due to highest risk, which represents the extreme end of the spectrum in comparison to controls and may exacerbate between-group differences, while not adequately representing those with less frequent/risky behaviours of concern. Additionally, the assumption that controls exhibited no behaviours of concern is possibly optimistic, assuming that lack of recordings and consultant PCAT evaluations were accurate. Finally, there may be discrepancies in recording of behaviour types; e.g. disinhibition were very rarely reported compared to self-neglect, which might represent differential likelihoods of documentation and consequently a source of bias. It is additionally a small sample, lacking adequate power, and almost all individuals exhibited multiple types of behaviour; consequently it was not possible to differentiate between the effects of behaviour types.

Finally, it is questionable whether psychological/behavioural rating scales are comparable to interval measurement scales, which could render statistical operations such as multiple regression potentially inappropriate if not – this is an ongoing debate. This study followed prior studies which assumed equivalence, permitting such analyses (Baker et al., 1966; Cohen & Cohen, 2003; Hawley et al., 1999; Wright & Masters, 1982). Similarly, although some authors contend that parametric analyses which allow for estimates of variance and better generalisability may be more suitable for large analyses, non-parametric analyses are unaffected by skewness and were therefore used in this study where normality assumptions were violated (Altman & Bland, 2009; Hawley et al., 1999; Tabachnick & Fidell, 2014; Turner-Stokes & Siegert, 2013).

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Appendix T: Theoretical/clinical implications

Several clinical/theoretical implications emerged. Importantly, it must be considered that multivariate models typically fit retrospective data better than prospectively-gathered data, and so confirmatory prospective studies of similar design would therefore be prudent to confirm/disconfirm these findings. It is however helpful that the generated models from this study are relatively simple, comprising few predictors, whereas more complex multivariate models of recovery predictor can be difficult to apply clinically – hopefully these models are more clinically useful (Gladman et al., 1992).

In terms of SI, a little-researched component in the internationally-used FIM+FAM (UK FIM+FAM Users Group, 2010), significant positive correlations indicated convergent validity with markers of 'real-world' engagement (hours of individual therapy and group activities). SI also significantly predicted Motor/overall recovery and length of stay, and significant negative correlations were evident with PCAT behavioural/cognitive ratings, indicating SI convergent/divergent validity with other ABI assessments. Associations with behavioural/cognitive ratings is reasonable because social difficulties are theorised to be related to behavioural (Winkler et al., 2006) and cognitive deficits (Milders, 2019). These findings jointly provide validation of the SI item, as well as corroboration of the PCAT, indicating that SI makes a useful contribution to rehabilitation assessment.

Mean weekly hours group activities, which largely comprised physiotherapy- or occupational therapy-led physical skills groups, was positively associated with Motor improvement. This agreed with past research and may be related to opportunities to practice strengthening exercises or relevant skills during such groups (Coulter et al., 2009; Hammond et al., 2015; Trahey, 1991). Improving access to group activities should consequently be prioritised in inpatient rehabilitation services. In addition to apparent physical gains, group activities are a cost-and resource-effective method to promote social relationships, reduce isolation/boredom, improve mood and deliver therapy

(Gerber & Gargaro, 2015; Häggström & Lund, 2008; Kenah et al., 2018; Masel & DeWitt, 2010; Patterson, Fleming & Doig, 2017; Patterson, Fleming, Doig & Griffin, 2017; Winkler et al., 2006). Inclusion of people with behaviours of concern may also help reduce occurrence of these behaviours, so promoting accessible groups for those with such difficulties is also important (Gerber & Gargaro, 2015). This study's finding regarding group benefits highlights the importance of assessing not just the individual with ABI, but their social context and available opportunities, when planning their rehabilitation pathway.

The behavioural data analyses indicated that those with behaviours of concern may achieve non-significantly greater gains to those with no such behaviours recorded (despite no significant different in admission FIM+FAM scores), which may be related to longer periods of stay in inpatient services. Since longer stay in inpatient rehabilitation is associated with greater risk of accidental injury or negative health events such as infection (Schimmel, 2003), it is important for services to examine why individuals with behaviours of concern have longer mean lengths of stay; it may for example be due to difficulties finding appropriate discharge placements, as such behaviours may make discharge to home/community placements more challenging (Tam, McKay, Sloan, & Ponsford, 2015; Winkler et al., 2006).

A final important consideration is that findings like the inverse association between age and Motor recovery, or particular aetiologies and Cognitive recovery, could be interpreted to mean that investing time/resources in individuals with particular characteristics post-ABI is less 'worthwhile'. It is of course essential that such associations be seen as probabilities across groups, not predictions about individuals – not least because this may create self-fulfilling prophecies which inadvertently harm individuals' prospects based on perceived likelihood of improvement (Stinear, 2010).

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Appendix U: Future research

Several recommendations can be made for future research. Regarding behavioural findings, although those with behaviours of concern made greater gains than controls as inpatients with intensive support, this may change in community environments once the support is lost and individuals may become withdrawn/isolated (Tam et al., 2015). Follow-up studies of such individuals in community settings would be valuable. Additionally, studies exploring changes in frequency/severity of such behaviours in relation to individual/group participation would be useful, to examine whether behavioural benefits are seen as in the community (Gerber & Gargaro, 2015). Finally, the behaviour analyses were underpowered (Appendix S); replication with an appropriately-sized sample is important.

Disambiguation of the role of individual therapy in rehabilitation is important. This study found no or negative associations with outcomes, but findings may have been confounded by therapy complexity (Dumas et al., 2004; Horn et al., 2005, 2015; Tepas et al., 2009; Wagner et al., 2003), therapeutic discipline (Cifu et al., 2003), and changes in effectiveness over time (Cullen et al., 2007). Given that many studies have identified positive roles for individual input in recovery (Carney et al., 1999; Cicerone et al., 2008; Cullen et al., 2007; Turner-Stokes et al., 2015), it cannot be ruled out as a predictor without exploring these confounds.

Similarly, exploration of the apparent physical benefits of group activities would be useful, e.g. identifying whether group type, lead therapeutic discipline or intensity contribute to gains. Examining whether group attendance specifically causes improved physical outcomes would be valuable, particularly in inpatient populations where evidence is limited. Additionally, few studies have compared group and individual outcomes; given the cost-effectiveness of groups in the financially-challenged NHS, identifying whether groups provide equivalent/better outcomes could yield important information for services (Coulter et al., 2009; Dobrez et al., 2004; Hammond et al., 2015; Trahey, 1991; Zanca et al., 2013).

Given that outcome differences were identified between conditions (anoxia being linked to poorer cognitive recovery other aetiologies), future studies might also explore recovery trajectories between types of ABI. Examination of the roles of race/ethnicity and education is also much-needed (Bhandari et al., 2005; Fernandes et al., 2012; Ottenbacher et al., 2008).

Future research should ideally comprise prospective multicentre studies to address limitations on generalisability, incorporating clinician-, self- and relative-report to gain a holistic overview of function/wellbeing (Appendix S) (Gladman et al., 1992; Nayar et al., 2016). It would also be useful to examine whether variables contributing to FIM+FAM improvements also predict future mood, employment and community reintegration, which FIM+FAM discharge scores predict up to ten years post-injury (Grauwmeijer et al., 2017; Valk-Kleibeuker et al., 2014), and to assess how well the models identified in this study generalise to non-specialist residential rehabilitation, or community settings.

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Appendix V: Personal learning/reflection

One of the main learning experiences during the DClinPsy for me was about how I cope with challenges. The doctorate is a busy time, which I made more difficult for myself by taking on additional employment (with my course line manager's agreement) and working on additional research. Some of this was seeking to stay within my comfort zone; research was a source of self-esteem when the course felt challenging or imposter syndrome loomed. Importantly, it also enabled me to keep my options regarding research-focused careers as well as clinical. In many ways, the extra research was a protective/positive factor.

However, the extra demands were challenging. Sometimes I found myself hurrying to meet deadlines which I perhaps should have renegotiated, e.g. when the Trust audit department requested feedback on data analysis by October 2018. Rather than admit this would put me under pressure and ask for extra time, which I knew from past experience with the department would be fine, I pushed myself to get the analysis done on time. This was not the only time I could have saved myself stress, but it stood out clearly as an avoidable burden when I wrote up the research process (Appendix K). At other times, such as when I needed to change research projects abruptly under time pressure (Appendix R), I made a quick decision about a new proposal which happened to be a workable idea, but I certainly could have benefited from taking time to think it over.

During second year I became stressed and run down, eventually having a car accident to which tiredness/distraction probably contributed (fortunately no one else was involved and I was not badly hurt). While I was still experiencing post-concussion symptoms, over one fortnight I had to prepare two major presentations and revise two papers, alongside DClinPsy placements/coursework. At this point I became acutely aware that I had bitten off more than I could chew, which was quite overwhelming. This experience became a turning point and I started to limit my workload, capping the number of projects I was working on and setting aside more time for friends, self-care and (most alien of all!) to do nothing. So although it was truly unpleasant when I felt that I couldn't cope, this was a really important learning experience.