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# The Effect of Admission Functional Independence on Early Recovery in Pediatric Traumatic and Nontraumatic Brain Injury

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**Objective:** To examine functional independence at admission as a predictor of outcomes during an initial inpatient hospitalization for a pediatric brain injury. **Participants:** A total of 531 pediatric inpatients with traumatic ($n = 298$) or nontraumatic ($n = 233$) brain injuries. **Design:** Retrospective analysis of data extracted from the Uniform Data System for Medical Rehabilitation. **Main Measure:** The Functional Independence Measure for Children, a measure of self-care, mobility, and cognitive independence. **Results:** Logistic regression analyses indicated that children with traumatic brain injury showed greater odds of making large functional gains in comparison with children with nontraumatic brain injury. For both groups, children entering rehabilitation with a moderate level of functional independence had the highest probability of making large gains. Children with a nontraumatic brain injury entering treatment with a high level of functioning made greater gains than those entering with low functioning. The opposite trend emerged for children with traumatic injuries. **Conclusions:** Level of functioning at admission may be a useful predictor of progress during an inpatient stay for youth with brain injuries. Children with nontraumatic brain injury entering treatment with low functioning are expected to make slower progress during hospitalization.
**Key words:** *acquired brain injury*, *functional outcomes*, *nontraumatic brain injury*, *pediatrics*, *rehabilitation*, *traumatic brain injury*, *WeeFIM*

ACQUIRED BRAIN INJURY (ABI) is one of the leading causes of lifelong disability in children and adolescents.[1] ABI is a broad term that refers to an injury to the brain resulting from traumatic or nontraumatic etiology. Traumatic brain injury (TBI) refers to damage to the brain that has occurred after birth as a result of physical trauma to the head. A nontraumatic brain injury (nTBI) refers to damage to the brain caused by factors such as anoxia, inflammation, vascular causes, metabolic toxicity, or neoplasms. Youth affected by an ABI requiring inpatient medical rehabilitation often experience chronic impairments, which impede the attainment of developmentally expected physical, cognitive, and behavioral functional goals.[1–4] These limitations typically necessitate ongoing support from caregivers beyond what would be expected for the child's chronological age.[5,6] Diminished functional independence not only is a source of stress on families but affects quality of life.[7] More research aimed at identifying predictors of functional independence is critical.

A growing literature on pediatric brain injury in the past several decades has demonstrated that the pathophysiology of a childhood brain injury is distinct from that of a brain injury sustained during adulthood.[8–12] Pediatric recovery from a brain injury is uniquely affected by the ongoing maturation of the developing brain. That is, brain regions required for the emergence and development of functional skills are adversely affected once cerebral maturation is interrupted.[13] This literature demonstrates that many factors contribute to the extent of functional developmental plasticity we may expect during recovery in the immature brain, making it a complex and still understudied area.[9] These findings highlight that we cannot rely on adult models of recovery when treating pediatric patients, given the multitude of different factors at play during neurological recovery in the immature brain.

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An important outgrowth of these findings is the establishment of rehabilitation hospitals with units that specialize in pediatric brain injury. Essential goals of inpatient care are to maximize recovery of independent functioning and minimize length of stay. Indeed, hospitals that have the resources that support the unique needs of childhood brain injury (eg, designated units and expert staff) have lower mortality rates and produce increased functional gains compared with units without a pediatric specialty.[14] Likewise, standardized assessments of functional outcomes developed specifically for children and adolescents are an essential component of rehabilitation.[15]

Functional outcomes refer to the child's present performance against criterion standards of care for activities such as toileting, locomotion, and social cognitive competencies such as language and communication skills. Standardized assessments for pediatric populations enable practitioners and researchers to compare the child's functional independence with developmentally expected behaviors. Standardized assessments assist with the production of an individualized recovery plan and allow for structured monitoring of recovery. Understanding differences in patterns of recovery based on specific characteristics at admission has great clinical value, potentially enabling a more precisely tailored treatment program in line with the goal-directed, client-centered approach to rehabilitation that typically leads to more successful outcomes.[16] Moreover, identifying factors at admission that predict outcomes at discharge could tell us which patients are likely to make the greatest gains, thereby allowing a more informed recovery prognosis.

The literature examining outcomes following pediatric ABI has focused on identifying preinjury and postinjury factors that predict specific social, cognitive, or physiological competencies. Demographic variables such as age, socioeconomic status, and family functioning have been linked to physical and cognitive outcomes.[17] Postinjury factors such as injury characteristics predicted poorer cognitive and psychosocial outcomes.[18,19] Few family resources, poor family functioning, and lower socioeconomic status were found to worsen relationships between severity and social competencies.[20] In addition, shorter time since injury and length of stay related to increases in functional outcomes at discharge.[21] Another variable that may affect ABI outcome is cause of injury. Differences in functional outcomes across traumatic and nontraumatic brain injuries during inpatient rehabilitation have been studied in adults[22,23]; however, there are far fewer pediatric studies. Among the available literature, research has shown that children with TBI made greater improvements in self-care,[24] mobility,[25] and caregiver assistance than children with nontraumatic brain injuries.[26] Importantly, no studies have compared the implications of pediatric ABI etiology for short-term recovery.

The purpose of the present study was to examine children's functional independence at admission as a predictor of gains in outcomes achieved during inpatient rehabilitation. A secondary aim was to compare potential differences in recovery of functional independence across brain injury etiology: nTBI and TBI. To accomplish this, we retrospectively investigated outcomes with admission and discharge measurements of functional independence using a standardized measure, the Functional Independence Measure for Children (WeeFIM).[27]

## METHODS

### Sample

A retrospective medical chart review was conducted at a pediatric rehabilitation hospital in the Northeastern United States. The hospital's data are archived at the Uniform Data System for Medical Rehabilitation (UDSMR), a registry for information on medical rehabilitation. All admissions with a primary diagnosis of ABI that occurred between 2001 and 2012 were screened for analysis resulting in 2157 records. Patients younger than 3 years, outpatient admissions, unplanned discharges, and repeat admissions were subsequently excluded from the sample. This resulted in a final sample of 531 cases, which were further categorized into 2 etiological groups: TBI ($n = 298$) and nTBI ($n = 233$). Because this investigation involved secondary analysis of existing data collected by the UDSMR, assessment of comorbid conditions was not available; thus, our data were limited to the primary diagnosis reported at inpatient admission. The nTBI group consisted of the following *International Classification of Diseases, Tenth Revision* (*ICD-10*) diagnostic categories: benign and malignant neoplasms, anoxia, anoxic/hypoxic encephalitis, intracranial abscess, and nonspecific etiology. This study was approved by the authors' local institutional review board.

### Measures

Functional independence at admission and functional gains between admission and discharge were the primary predictor and outcome for this analysis, respectively. Functional independence was measured with the WeeFIM, a common assessment administered by trained staff measuring global changes in functional recovery during inpatient hospitalization. The WeeFIM was developed from the adult Functional Independence Measure (FIM), including 18 items to capture the domains of self-care, mobility, and cognition.[27] The WeeFIM has been found to have strong validity and reliability across diverse clinical pediatric populations.[28,29]

Our sample included children ages 3 to 21 years. Recognizing that our sample encompasses a wide range of developmental stages, we standardized the raw WeeFIM scores for each domain with Developmental Functional Quotients (DFQs).[28] DFQ scores range from 14 to 100, with higher values indicating greater independence. Due to notably right skewed distributions for the scale scores for each domain, tertiles were used to create ordinal variables categorizing low, moderate, and high functional independence at admission. Specifically, for the self-care domain, individuals categorized with low functioning at admission corresponded with DFQ scores that ranged from 14 to 21; children in the moderate group had scores that ranged from 22 to 58; individuals grouped in the high category earned scores ranging from 60 to 100. For mobility, low functioning at admission corresponded with scores of 14 to 16; the moderate category referred to scores from 17 to 45; high mobility functioning at admission encompassed scores ranging from 47 to 100. For cognition, children categorized in the low functioning group had scores ranging from 14 to 23; individuals grouped in the moderate functioning group earned scores ranging from 25 to 61; individuals categorized in the high group had scores ranging from 62 to 100.

Similarly, participants' scores were grouped according to tertiles representing low, moderate, and large gains over the course of rehabilitation. That is, individuals categorized as making low self-care gains corresponded with change scores from 0 to 13; individuals in the moderate group referred to those with change scores from 14 to 33; children who made large gains were those with scores from 34 to 85. For mobility, individuals categorized in the low gains group included those with change scores from 0 to 22; children in the moderate group had change scores from 23 to 42; individuals categorized in the large gains group had change scores ranging from 45 to 82. For cognition, children with change scores ranging from 0 to 5 fell in the low gains group; scores in the moderate gains group ranged from 6 to 25; scores in the large gains group ranged from 27 to 85.

A sensitivity analysis was conducted to evaluate the influence of ceiling effects on the potential to attain moderate or high levels of functional gains. We identified a subgroup of children who were high functioning at admission, as these represented children who may not have achieved moderate or high functional gains due to ceiling effects. All models were then retested in the sample that excluded these top 10% of scores for each scale. Results of this alternate analysis further supported the contention that our tertile scores were robust. That is, for each subscale, across both the TBI and nTBI groups, the direction and significance of the observed associations between admission functioning and functional gains using the full sample were comparable.

### Statistical analyses

Descriptive statistics were used to assess differences in the sample characteristics by TBI and nTBI groups. We used ordered logit models stratified by ABI type (TBI vs nTBI) to examine how functional status at admission predicted the ordinal categories of functional gains at discharge. Tests of the proportional odds assumption suggested that the distance between categories was not proportional for self-care. Supplemental analyses were used to evaluate comparisons in model fit between the ordered, generalized ordered, and multinomial logit models for each of the 3 domains. Results from comparisons of the Bayesian Information Criterion and likelihood ratio tests suggested that the ordered logit was a more optimal fit for models predicting mobility and cognition gains, and therefore, for consistency and comparability, we fit a series of ordered logit approach for all 3 outcomes. The odds ratios (ORs) calculated in the multivariate models are interpreted as the odds of being in a functional group that was greater than $k$ compared with those less than or equal to $k$, where $k$ is the cumulative level of functional gains. All of the ORs included in the Results and tables indicated the likelihood of making moderate or large gains in comparison to low gains (reference category). All multivariate models were adjusted for age group, length of inpatient hospitalization, and gender.

## RESULTS

The sample characteristics are presented in Table 1. The majority of this sample was male and older than 13 years. Bivariate tests indicated significant differences in age and gender composition by ABI group, with an overrepresentation of males and older children among cases with TBI and more parity among the nTBI subgroup; this is consistent with other studies.[30,31] There were no significant differences in length of stay, with a total sample average of 6 weeks, and means of 41.5 (standard deviation = 49.3) and 43 (standard deviation = 43.1) for the TBI and nTBI groups, respectively. Table 1 also presents the distributions for the DFQ tertiles for WeeFIM admission scores and gains by ABI group. Across each domain, children treated for TBI are modestly overrepresented in the high independence category, whereas children with nTBI are more likely to be assessed with low functional independence in self-care ($\chi^2 = 11.69$, $df = 2$, $P = .003$), mobility ($\chi^2 = 11.69$, $df = 2$, $P = .003$), and cognition ($\chi^2 = 6.23$, $df = 2$, $P = .044$). The ABI group differences are even more apparent when comparing the distributions across levels of functional gains. Specifically, children with TBI were disproportionately more likely to make large gains over the course of rehabilitation compared with children with nTBI in self-care ($\chi^2 = 19.90$, $df = 2$, $P = .000$),

**TABLE 1** *Sample characteristics by ABI type (n = 531)*

| | Total ($n = 531$) n (%) | TBI ($n = 298$) n (%) | nTBI ($n = 233$) n (%) |
|---|---|---|---|
| *Control variables* | | | |
| Males | 329 (62) | 210 (70) | 119 (51.1)[a] |
| Age group, y | | | |
| 3-7 | 102 (19.2) | 38 (12.8) | 64 (27.5) |
| 8-12 | 121 (22.8) | 55 (18.4) | 66 (28.3) |
| ≥13 | 308 (58) | 205 (68.8) | 103 (44.2)[a] |
| *Dependent variables* | | | |
| Self-care gains | | | |
| Low | 175 (32.9) | 77 (25.8) | 98 (42.0) |
| Moderate | 180 (34.0) | 102 (34.2) | 78 (33.5) |
| High | 176 (33.1) | 119 (40.0) | 57 (24.5)[a] |
| Mobility gains | | | |
| Low | 194 (36.5) | 88 (29.5) | 106 (45.5) |
| Moderate | 170 (32.0) | 91 (30.6) | 79 (33.9) |
| High | 167 (31.5) | 119 (39.9) | 48 (20.6)[a] |
| Cognitive gains | | | |
| Low | 183 (34.5) | 78 (26.2) | 105 (45.1) |
| Moderate | 196 (36.9) | 112 (37.6) | 84 (36.0) |
| High | 152 (28.6) | 108 (36.2) | 44 (18.9)[a] |
| *Independent variables* | | | |
| Self-care admission | | | |
| Low | 176 (33.2) | 85 (28.5) | 91 (39.1) |
| Moderate | 176 (33.2) | 95 (31.9) | 81 (34.8) |
| High | 179 (33.8) | 118 (39.6) | 61 (26.2)[b] |
| Mobility admission | | | |
| Low | 159 (30.0) | 74 (24.8) | 85 (36.5) |
| Moderate | 187 (35.2) | 104 (34.9) | 83 (35.6) |
| High | 185 (34.8) | 120 (40.3) | 65 (27.9)[b] |
| Cognitive admission | | | |
| Low | 171 (32.2) | 84 (28.2) | 87 (37.3) |
| Moderate | 182 (34.3) | 103 (34.6) | 79 (33.9) |
| High | 178 (33.5) | 111 (37.2) | 67 (28.8)[c] |

Abbreviations: ABI, acquired brain injury; nTBI, nontraumatic brain injury; TBI, traumatic brain injury.
[a] $P < .001$.
[b] $P < .01$.
[c] $P < .05$.

mobility ($\chi^2 = 25.12$, $df = 2$, $P = .000$), and cognitive independence ($\chi^2 = 27.38$, $df = 2$, $P = .000$).

## Multivariate findings

The next step involved modeling the relationships between admission functioning and functional gains for ABI group differences of individual characteristics (ie, gender, age group, and length of stay, which was logged for all further analyses due to the skewed distribution). The proportional ORs demonstrating the predictive relationships between functional independence level at admission and functional gains for children treated for nTBI and TBI are presented in Table 2.

### *Non-traumatic brain injury*

Among youth with nTBI, the results suggest that functional status at admission significantly predicted levels of gains made over the course of rehabilitation. For self-care, children who were admitted with moderate independence were 3 times as likely to make moderate or large gains compared with those who made small gains, after adjusting for differences in age, gender, and length of stay, as seen in Table 2. Children admitted with high levels of self-care independence were not more likely to make moderate or large gains compared with children admitted with low independence. Similar patterns emerged across the other 2 domains. Moderate levels of mobility and cognition independence at admission predicted greater likelihood of moderate and large gains over rehabilitation in comparison to those making low gains (OR = 7.33; OR = 4.15, respectively). The odds of children with high mobility and cognitive independence at admission making large gains were approximately twice that of children admitted with low levels of independence, although this difference was not statistically significant. These data suggest that the greatest gains may be expected among children with nTBI admitted for rehabilitation with moderate independence, presumably because the damage is very extensive in the low functioning group; for the high functioning group, there is less room for improvement. The differences in the probabilities of low, moderate, and high functional gains by initial status at the time of admission are depicted in Figure 1.

### *Traumatic brain injury*

For self-care and mobility, moderate functioning at admission significantly predicted greater likelihood of moderate and high gains in comparison to low gains for self-care (OR = 3.84, $P < .001$) and mobility (OR = 6.88, $P < .001$), respectively. In other words, children with TBI entering inpatient rehabilitation with a moderate level of self-care and mobility functioning at admission could be expected to make greater progress during inpatient rehabilitation in comparison with children with low initial independence. Unlike the children with nTBI, there was no difference in the likelihood of making moderate or large gains in cognition between children with TBI with low or moderate independence at admission. Also in contrast to the nTBI group, we observed a consistently negative pattern across all 3 domains among the children with TBI who were categorized as highly independent at admission; the most independent group was less likely to make moderate or large gains at discharge in self-care (OR = 0.31, $P < .01$), mobility (OR = 0.36, $P < .05$), or cognition (OR = 0.10, $P = .001$). Overall, these data suggest that among children with TBI the greatest gains may be expected for children admitted

**TABLE 2** *Ordered logit models predicting functional gains during rehabilitation (n = 531)[a]*

| | Functional gains—nTBI | | | Functional gains—TBI | | |
|---|---|---|---|---|---|---|
| | **Self-care OR (95% CI)** | **Mobility OR (95% CI)** | **Cognition OR (95% CI)** | **Self-care OR (95% CI)** | **Mobility OR (95% CI)** | **Cognition OR (95% CI)** |
| *Admission domain*[b] | | | | | | |
| Self-care | | | | | | |
| Moderate | 3.10[c] (1.66-5.81) | — (—) | — (—) | 3.84[c] (1.85-7.94) | — (—) | — (—) |
| High | 1.53 (0.75-3.11) | — (—) | — (—) | 0.32[d] (0.14-0.70) | — (—) | — (—) |
| Mobility | | | | | | |
| Moderate | — (—) | 7.33[c] (3.66-14.7) | — (—) | — (—) | 6.88[c] (3.27-14.5) | — (—) |
| High | — (—) | 2.00 (0.92-4.38) | — (—) | — (—) | 0.36[e] (0.15-0.85) | — (—) |
| Cognition | | | | | | |
| Moderate | — (—) | — (—) | 4.15[c] (2.18-7.93) | — (—) | — (—) | 1.07 (0.55-2.09) |
| High | — (—) | — (—) | 1.92 (0.95-3.91) | — (—) | — (—) | 0.10[c] (0.04-0.22) |
| *Model statistics* | | | | | | |
| $\chi^2$ | 18.94[e] | 48.7[c] | 30.5[c] | 97.7[c] | 117.8[c] | 97.5[c] |
| *df* | 6 | 6 | 6 | 6 | 6 | 6 |

Abbreviations: CI, confidence interval; nTBI, nontraumatic brain injury; OR, odds ratio; TBI, traumatic brain injury.
[a]All models are adjusted for gender, age groups, and inpatient length of stay (logged).
[b]The omitted reference category for each functioning domain at admission was low independence, such that the odds of making moderate or large gains was compared with those making low gains.
[c]$P < .001$.
[d]$P < .01$.
[e]$P < .05$.

with low and moderate independence. As with nTBI, the group that is already high functioning at admission may be expected to exhibit relatively fewer functional gains because they have less room for improvement. The differences in the probabilities of low, moderate, and high functional gains by initial status at the time of admission in functional gains are depicted in Figure 2.

## DISCUSSION

It is widely known that many factors influence recovery from a pediatric brain injury. Delineating typical recovery of functioning across traumatic and nontraumatic etiologies seems especially crucial if one wishes to assist in the development of theoretical models of recovery and provide a more specific prognosis for families at the start of their child's treatment. This study represents the first in over a decade to examine differential gains in functional independence between youth with traumatic and nontraumatic brain injuries. Moreover, this is the first study to examine differing levels of function at admission as predictors of amount of change made during rehabilitation of a pediatric brain injury.

When comparing overall differences in gains made across the domains of self-care, mobility, and cognition, our findings replicated and extended older studies with pediatric ABI. Our data showed that there were greater gains in functional independence in the TBI group than in the nTBI group, which is consistent with previous studies[27,31,32] and in adult populations.[22,23] Our study extended this literature by also looking at cognitive functioning. We found that youth with TBI were also

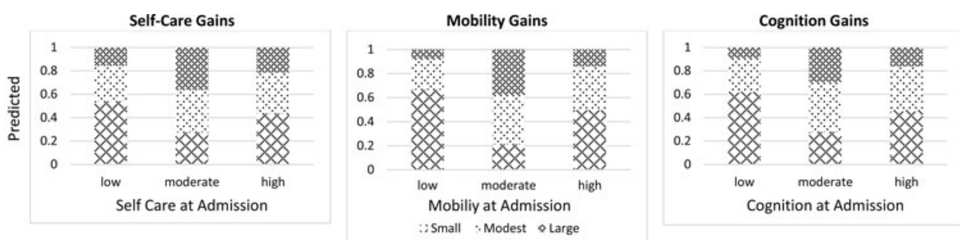


**Figure 1.** Predicted probabilities in gains in functional independence by admission status for children with nontraumatic brain injury ($n = 233$). The 3 crosshatching patterns illustrate the probability of making small, moderate, and large gains across level of functioning at admission.

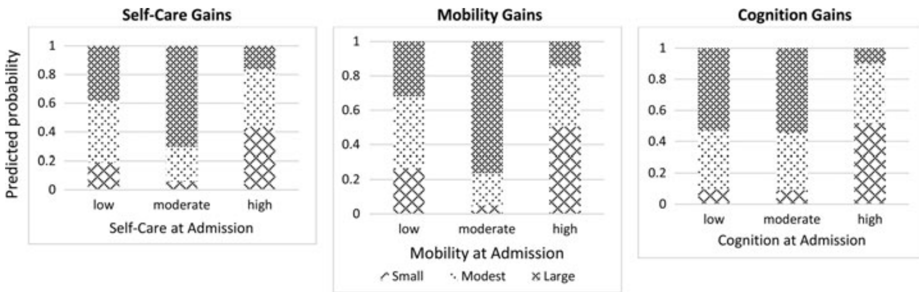


**Figure 2.** Predicted probabilities in gains in functional independence by admission status for children with traumatic brain injury ($n = 298$). The 3 crosshatching patterns illustrate the probability of making small, moderate, and large gains across level of functioning at admission.

more likely to make larger gains in self-care and cognition functional independence compared with youth with nTBI.

Next, we examined the predictive value of level of functional independence at admission for progress during hospitalization. For both groups, a moderate level of functional independence was a significant predictor of achieving moderate to large gains during inpatient rehabilitation across self-care and mobility. Thus, youth admitted with a moderate level of functional independence could expect to make the greatest gains during inpatient rehabilitation. A moderate level of functioning on the cognition domain at admission significantly predicted greater outcomes for the nTBI group but not for the TBI group.

Further differences emerged when comparing outcomes between clinical groups on high versus low functioning at admission. A closer look at the probability analyses found that children with TBI and nTBI with high mobility scores at admission showed the same likelihood of making large gains. However, differences between the TBI and nTBI groups were evident when looking at the group with low scores at admission, such that children with TBI with low mobility functioning at admission were more than 4 times as likely to make large gains than children with nTBI. These data suggest that youth with nTBI with low or high functioning at admission have a high probability of making small mobility gains, and this contrasts with what may be expected in youth with TBI.

Youth with nTBI with high functioning scores were more likely to make greater gains in both self-care and cognition independence. We again found an opposite trend for youth with a TBI such that youth with TBI with low versus high functioning at admission could be expected to make greater gains in self-care and cognition. This finding runs somewhat contrary to what is found in the adult TBI literature. In a large cohort of adults recovering from a TBI, individuals with low functional ability at admission showed persistently low total FIM scores at discharge and at a 1-year follow-up assessment.[33] In the present study, those with low functioning at admission in the TBI group did show improvements at discharge, although not as great as individuals with moderate level of independence at admission. These disparate findings between the adult and pediatric populations further support the theory that pediatric and adult patterns of recovery from a TBI are distinct.[13]

Our finding that youth with nTBI with low functioning at admission showed slower recovery may suggest less neurocognitive resilience than the TBI group. From a learning theory perspective (ie, that new skill learning is acquired through repeated pairings that result in greater synaptic strength between the associated neurons),[34] we can hypothesize that the lesser progress demonstrated by the low functioning group could be reflective of a delay in neurobiological communication necessary for new learning. Thus, we tentatively suggest that children and adolescents with nTBI in the low functioning group sustained neurological damage that was especially extensive, resulting in greater difficulty recovering functional independence. Because we have limited information about the extent of neurological injury, we suggest future studies include more discrete information such as characterization through neuroimaging of participants in the nTBI and TBI groups.

## Limitations

There are a few limitations of this study. The UDSMR database does not include indicators of injury severity. Acute indicators of severity (eg, Glasgow Coma Scale score) have been found to affect WeeFIM scores at discharge.[21] Including this information in our analyses would have represented a more comprehensive model. We utilized baseline functional status at admission as an assumed best indicator of severity. Second, a drawback of retrospective analyses, we did not have information regarding additional variables that have been known to affect functional outcomes such as time to admission since injury, premorbid status (eg, orthopedic or spinal injuries), or socioeconomic status. Lastly, the WeeFIM measure has strengths in terms of robust psychometric properties; however, it is limited by its commonly found nonnormal distribution, which can impede comparisons across groups.[28]

## CONCLUSIONS

Results of this study contribute to the literature on rehabilitation in pediatric brain injury by revealing patterns of short-term recovery during inpatient rehabilitation using a multidimensional measure of functional independence, which had not been studied in recent years. Our results also extend theory by considering the role of the patient's level of functioning at the time of admission as a predictor of recovery progress, finding that this variable is a significant contributor to outcomes from inpatient rehabilitation for a brain injury.

The results of this study are useful for clinicians who need to prepare families for the challenges of rehabilitation. Estimates of slower progress based on brain injury etiology, functional independence domain, and level of functioning at admission can enable staff to provide more focused care for those expected to make small gains to potentially offset the vulnerabilities these factors represent. Future studies could build upon this work by including greater detail regarding neurological injury and characteristics of preinjury functioning. Examination of these factors is an essential next step in building more comprehensive outcome models to permit clinicians to provide more astute recovery prognosis and a more tailored treatment plan.

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