International Journal of Physical Medicine & Rehabilitation

Lewis, et al., Int J Phys Med Rehabil 2017, 5:1
DOI: 10.4172/2329-9096.1000390

Research Article OMICS International

Examination of Post-Hospital Residential Brain Injury Rehabilitation Outcomes Across the Age Spectrum

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Received date: January 17, 2017; **Accepted date:** January 30, 2017; **Published date:** February 03, 2017

Abstract

Objectives: To evaluate change in functional independence observed admission to discharge from post-hospital brain injury residential rehabilitation programs among a large group of chronic TBI adults and children and to determine the impact of participant age on those outcomes.

Methods: Six hundred and fifty one adults and children with moderate to severe traumatic brain injury (TBI) were assigned to one of six groups based on age: (1) 5-17, (2) 18-29, (3) 30-39, (4) 40-49, (5) 50-59, and (6) 60 and older. Functional status was assessed at admission and discharge with the MPAI-4. Differences among groups were evaluated using conventional parametric tests. Rasch analysis established reliability and construct validity of MPAI-4 data.

Results: Rasch analysis demonstrated satisfactory construct validity and internal consistency (Person reliability=0.90-0.94, Item reliability=0.99) for the admission and discharge MPAI-4s. Controlling for LOS and onset-to-admission interval, a RM MANCOVA revealed that each age group showed significant improvement in MPAI-4 Abilities, Adjustment, and Participation indices from admission to discharge ($p<0.001$). Improvement observed from admission to discharge was not significantly different across age groups.

Conclusions: Post-hospital residential brain injury rehabilitation was effective in reducing disability for participants in each age group. Age was not a factor in rehabilitative outcome. The oldest participants on average realized a reduction in disability equivalent to that observed in the youngest participants independent of length of stay duration.

Keywords: TBI; Age effects; Outcomes; Post-hospital rehabilitation; MPAI-4; Rasch analysis; Functional measurement

Introduction

Neuroscience research suggests that elderly adults should not recover from TBI as well as younger adults and children [1]. Beyond the age of 60, the typical aging brain experiences anatomical and molecular changes including dendritic atrophy, myelin sheath deterioration, restricted blood flow and diminished levels of dopamine and serotonin; two neurotransmitters important for learning and memory [2]. Due to a declining plasticity, when an elderly brain is damaged, other cells are less able to modify and compensate resulting in slowed or limited recovery [1]. Notwithstanding this evidence, the research on the effects of age on functional outcome following TBI has been equivocal [3].

Research outcome studies support the notion that recovery from TBI is poorer in elderly persons [4-6]. Leblanc and his colleagues examined outcomes from 2,327 TBI patients discharged from Level I trauma centers [7]. They found that persons over 60 years of age experienced poorer outcomes than those less than 60 years of age as measured by the Functional Independence Measure (FIM) and the Extended Glasgow Outcome Scale. Similarly, Senathi-Raja, Ponsford, and Schanberger reported age and time post-injury to be significant factors in patients' emotional recovery following TBI [6]. Chiavaroli et al. also observed age to be an important variable determining functional outcomes from acute rehabilitation hospitals, with better outcomes associated with younger TBI patients [5]. In a study of outcomes up to five years post-injury, Marquez de la Plata and his colleagues reported that older adults experienced a greater decline in functional independence than younger adults [4].

However, not all research supports age as a major determinant of outcome. In a study comparing outcomes for TBI patients 55 years and older to a matched sample of patients 18 to 54 years of age, Cifu et al. observed significant functional improvement in both groups, although the older patients experienced longer length of stays and greater costs to achieve those outcomes [8]. A similar result was obtained by Irdesel, Aydiner, and Akgoz in their study following 30 TBI patients from intensive care through discharge from a rehabilitation hospital [9]. All patients realized significant functional gains, although recovery was slower for adults over the age of 45. Pedersen, Severinsen, and Nielsen examined admission and discharge FIM data from 411 consecutive TBI patients admitted to hospital rehabilitation [10]. Total FIM change across three age groups (18-39, 40-64, 65 and older) was not statistically different. However, a more in-depth item analysis revealed a strong age effect with older patients performing more poorly on specific FIM items.

Taken together, the current research supports the notion that otherwise healthy TBI adults 60 years and older can achieve significant functional improvement following in-patient hospital rehabilitation. However, the question remains how well this population responds to continued care in post-hospital rehabilitation. Several studies have demonstrated the efficacy of post-hospital TBI rehabilitation [11-13], but to date no studies have simultaneously compared outcomes across the age spectrum for this level of care. Therefore, the present study seeks to determine if differences exists in the functional outcomes following post-hospital residential brain injury rehabilitation across six different age groups: 5-17, 18-29, 30-39, 40-49, 50-59, and 60 and older.

Methods

Subjects

The study sample was selected from 2,457 neurologically impaired individuals with consecutive discharges from 32 post-hospital residential rehabilitation programs in 15 states from 2011 to 2016. From the population of 2,457, a sample of 651 individuals met study inclusion criteria: diagnosed with a traumatic brain injury, minimum length of stay of 2 months, minimum chronicity (onset of injury to admission interval) of 2 months and admitted and discharged from active residential neurorehabilitation. The extent and nature of their disability prevented these participants from living independently. Due to the chronicity of this population, Glasgow Coma Scale scores (GCS) at the scene of injury or upon admission to the trauma center were largely unavailable. Therefore, severity of disability upon admission to program was assessed by MPAI-4 Total T-scores. This score provides an indication of disability level compared to a referenced group of neurologically impaired persons [14]. The mean length of stay for the entire sample was 6.34 months. The mean onset of injury to admission was 17.31 months. The average age for the total sample was 39.57 years. Detailed demographic characteristics of the sample including MPAI-4 Total T-scores at admission are presented in Table 1.

Gender	
Male	77%
Female	23%
Age (years)	
Mean	39.57
SD	16.3
Range	5-81
Time Since Injury (months)	
Mean	17.31
SD	23.74
Range	2-117
Length of Stay (months)	
Mean	6.34
SD	4.61
Range	2-25
Race	
African American	13%
Asian/Pacific	1%
Caucasian	73%
Hispanic	9%
Multi-racial	4%
Severity of TBI (Based on MPAI-4 Admission Total T-Score) Mild (<40)	1.5%
Mild-moderate (40-49)	17.7%
Moderate (50-59)	32.4%
Severe (60+)	48.4%

Table 1: Total sample demographics and injury related variables (n= 651).

To examine the impact of age on outcome, the study sample was divided into the following 6 age groups: 5-17 (n=53), 18-29 (n=166), 30-39 (n=106), 40-49 (n=110), 50-59 (n=136) and 60+ (n=80). Demographic characteristics of each group are presented in Table 2.

	Age groups					
	5-17 (n=53)	18-29 (n=166)	30-39 (n=106)	40-49 (n=110)	50-59 (n=136)	60+ (n=80)
Age Mean SD	13.8 3.7	23.2 3.6	34.4 2.97	45.2 2.5	54.5 2.7	64.34 4.86
Gender Male Female	64% 36%	74% 26%	78% 22%	87% 13%	81% 23%	80% 20%

Onset to admission (months) Mean SD Range	39.9 37.5 2-109	17.1 21.39 2-116	21.2 28.2 2-117	13.9 16.8 2-96	13.9 20.4 2-103	8.1 10.0 2-55
Length of Stay (months) Mean SD Range	6.9 4.1 2-19	6.6 4.9 2-25	6.3 4.7 2-24	5.6 4.1 2-21	6.6 4.7 2-24	6.0 4.6 2-22

Table 2: Demographics for Age Groups.

Measure

Participant functioning was assessed using the Mayo-Portland Adaptability Inventory-4 [15] at the time of admission and time of discharge from the treatment facilities involved in the study. Specifically, the MPAI-4 consists of 29 items rated from 0 to 4 on a 5-point scale, where 0 represents no limitations and 4 represents a severe problem interfering with activity more than 75% of the time. Raw scores on the 29 items are converted to T-scores within three subscales: Abilities Index (physical, communication, and cognitive skills), Adjustment Index (emotional and behavioural skills), and Participation Index (contextual skill application). T-scores have a mean of 50 and a standard deviation of 10. Higher T-scores indicate greater disability. When applied to child/adolescent populations, MPAI-4 scoring is modified to appropriate developmental norms. Used primarily in post-hospital rehabilitation settings, the MPAI-4 has undergone rigorous psychometric testing and has proven reliability and validity as determined through Rasch analysis, Item Cluster, Principle Component Analyses (PCA), and measures of concurrent and predictive validity [14].

T-scores derived for the three MPAI-4 indices at admission and discharge constituted the dependent variables for the study. Table 3 lists the specific items rated for the Abilities, Adjustment, and Participation Indices.

Abilities Index	Adjustment Index	Participation Index
Mobility	Anxiety	Initiation
Use of hands	Depression	Social contact
Vision	Irritability, Anger, Aggression	Leisure skills
Audition	Pain and Headache	Self-care
Dizziness	Fatigue	Residence (home skills)
Motor speech	Sensitivity to mild symptoms	Transportation
Verbal communication	Inappropriate social interactions	Paid employment
Attention/Concentration	Impaired awareness	Other employment
Memory		Money management
Fund of information		
Problem solving		
Visual spatial abilities		

Table 3: MPAI-4 29 items by Index.

Rehabilitation treatment

Each participant was admitted to residential neurorehabilitation programs. Both adult and child/adolescent participants received physical therapy, occupational therapy, speech therapy, recreation, counseling (based on need), case management, and medical management provided by nursing and physicians specializing in physical medicine and rehabilitation. Child/adolescent participants also attended certified schools or received instruction from certified teachers. Behavioural analysis was provided for cases requiring more extensive modification to reduce inappropriate behaviours and increase positive replacement behaviours.

Participants were discharged upon substantial attainment of individualized rehabilitation goals which were determined by the treatment team with input from participant, family, and funder.

Factors such as predicted rehabilitation potential, discharge environment, support system needs, and funding constraints were considered in establishing the discharge goals. Progress toward goals was monitored weekly and summarized monthly by the treatment professionals until discharged.

Procedure

Participants were evaluated upon admission by each program's multidisciplinary treatment team members. Once individual discipline assessments were completed, each participant was then evaluated within approximately two weeks of admission using the MPAI-4 by treatment team consensus. Discharge MPAI-4s were completed in a similar fashion by that treatment team within the final week of the participant's stay. To reduce team scoring bias (eg., reliability), monthly training was provided by experts external to the treating team. To ensure construct validity and item reliability, separate Rasch analyses were conducted on admission and discharge MPAI-4s. The results of all evaluations were compiled into a national database and combined with participant demographic data.

Statistical analysis

Rasch analysis was conducted for purposes of determining reliability and construct validity of the MPAI-4 as a measure of disability following brain injury. A repeated measures multivariate analysis of co-variance (RM MANCOVA) was provided to evaluate change scores on Abilities, Adjustment, and Participation Indices from admission to discharge. Differences in outcome as a function of age group were determined using this statistical approach. Analyses were performed using SPSS version 22 for the RM MANCOVA and follow-up tests while Winsteps version 3.81 was used to conduct Rasch analyses.

Results

Reliability and validity of MPAI-4

Rasch analysis determines the reliability of an assessment tool by comparing expected from the actual values of the items comprising a measure. The analysis reveals the extent of item and person fit for measurement of human performance. According to Malec and Lezak (2008) this analysis "has been used to evaluate how items contributing to a measure represent the underlying construct, and how well the items provide a range of indicators that reliably differentiate among people rated with the measure" [15]. Key statistics provided by Rasch analysis are Person and Item Reliability and Person and Item Separation. In general, reliability refers to the reproducibility of results obtained by a measure. Specifically, Person Reliability indicates how well items comprising a measure distinguish among individuals (e.g. those possessing a lot or a little of the construct measured) while Item Reliability refers to whether test items relate to each other in a consistent way in describing a disparate group of individuals. A coefficient of 0.80 or greater is considered acceptable for Person Reliability, while a coefficient of at least 0.90 is optimal for Item Reliability [16]. For the current sample, Person Reliability coefficients were 0.90 and 0.94 respectively for admission and discharge MPAI-4s. Item Reliability was 0.99 for both admission and discharge MPAI-4s.

Separation values indicate "the extent to which items distinguishes among people (Person Separation) and are distinct from each other (Item Separation)" [14]. Specifically, Person Separation values indicate the number of performance levels detected by a measure. For example, a Person Separation index of 2.00 means that two levels of performance can be reliably identified. The present study found Person Separation indices of 3.01 and 3.81 respectively for admission and discharge MPAI-4s indicating 3.00+ levels of performance reliably identified. Item Separation refers to the extent to which items on a test are consistently ranked from least difficult to most difficult. Low Item Separation (<3.00) imply that the item difficulty hierarchy is not reliable [16], whereas magnitudes exceeding 3.00 indicate greater consistency of item hierarchy. Item Separation indices for the study sample were 15.63 and 17.92 respectively for admission and discharge MPAI-4s, revealing a strong hierarchical item structure.

With the reliability and construct validity of the MPAI-4 established, results were analysed to determine the effect of age on outcome following post-hospital residential brain injury rehabilitation.

Multivariate homogeneity of variance

Prior to interpreting the results of the RM MANCOVA, the Box's M test was examined to determine the equality of covariance of the dependent variables across age groups. This result was non-significant ($p<0.025$; significance determined at alpha=0.001), meeting the assumption for multivariate homogeneity of variance (equality of variance between groups). To further test the equivalence of groups with regard to severity of disability at admission, a one-way ANOVA was performed on total T-scores across age groups. This analysis revealed no significant effect of age group, ($p<0.48$, n.s.). With the equivalence of groups at admission established on the dependent measures and severity of functional disability, results of the RM MANCOVA were interpreted to determine the impact of age on outcome following post-hospital residential rehabilitation.

Change admission to discharge

After controlling for length of stay and chronicity (onset-to-admission interval), the RM MANCOVA revealed a significant main effect for pre-post testing, $F(1,643)=329.33$ $p<0.0005$, Wilks Lambda=0.66, partial $eta^2=0.34$, power to detect=1.00. Follow-up paired sample t tests revealed that within each age group, scores on the MPAI-4 subscales were significantly lower (less disability) from admission to discharge. Table 4 presents the paired sample T-values, significance levels, and Cohen's d effect sizes for each pre-post comparison on the Abilities, Adjustment, and Participation measures.

	Paired-sample T-Values* (Cohen's d effect size)		
Age Group	Abilities Index	Adjustment Index	Participation Index
5-17 (n=53) Effect size	6.05 (0.82)	6.80 (0.95)	6.50 (0.91)

18-29 (n=166) Effect size	12.89 (1.00)	12.99 (1.01)	14.05 (1.10)
30-39 (n=106) Effect size	10.15 (0.99)	9.13 (0.90)	10.50 (1.04)
40-49 (n=110) Effect size	12.74 (1.20)	10.15 (0.98)	10.70 (1.02)
50-59 (n=136) Effect size	12.02 (1.04)	9.95 (0.85)	12.69 (0.92)
60+ (n=80) Effect size	10.74 (1.20)	8.91 (0.99)	10.46 (1.20)
*p<0.001 for each comparison			

Table 4: Paired-sample T-values and effect sizes for change admission to discharge for age groups on MPAI-4 indices.

Impact of age on outcome

The RM MANCOVA did not find significant main or interaction effects for age group on performance on the MPAI-4 measures at admission or discharge. Improvement observed from admission to discharge on each of the dependent measures did not differ as a function of age group. Mean T-scores and standard deviations observed at admission and discharge for each age group are presented in Table 5.

Admission Scores	Age Groups					
MPAI-4 Index	5-17	18-29	30-39	40-49	50-59	60+
Abilities	56.40 (16.20)	58.80 (12.30)	57.90 (10.90)	57.80 (10.40)	57.80 (9.80)	59.80 (10.10)
Adjustment	59.90 (9.60)	60.60 (10.30)	60.70 (9.40)	58.50 (9.70)	58.80 (10.60)	58.20 (9.10)
Participation	56.60 (9.30)	58.90 (10.40)	57.50 (9.60)	56.30 (10.00)	58.30 (10.10)	58.80 (8.70)
Discharge Scores						
MPAI-4 Index						
Abilities	50.70 (16.30)	51.00 (11.90)	51.20 (11.10)	50.30 (11.50)	50.30 (11.00)	52.10 (10.70)
Adjustment	51.90 (10.50)	52.40 (10.30)	54.10 (10.40)	51.80 (8.90)	51.00 (10.30)	50.60 (9.40)
Participation	50.50 (9.30)	51.30 (11.10)	51.00 (10.50)	50.50 (10.80)	50.30 (10.40)	51.10 (9.70)

Table 5: Means (Standard Deviations) for MPAI-4 indices at admission and discharge across age groups.

Discussion

Meaningful evaluation of TBI outcomes requires functional measurement with proven reliability and validity. Consistent with prior research from Malec & Lezak [15], Rasch analyses performed at admission and discharge found the MPAI-4 to be psychometrically sound and a reasonable measure to evaluate the impact of disability and performance of skills following traumatic brain injury. Meeting these criteria lends greater confidence that age may not have the impact that was once considered a negative barrier to recovery.

First, all six age groups realized significant reduction in disability following participation in post-hospital rehabilitation programs. This finding is particularly important given that the groups were fairly chronic with onset to admission intervals ranging from 8.1 months (60+ age group) to 39.9 months (5-17 age group). Changes observed in each of the three MPAI-4 indices across each age group were statistically significant, and also of large magnitude with Cohen's d effect sizes ranging from 0.82 to 1.2. This finding offers support for the benefit of post-hospital rehabilitation for TBI survivors across the age spectrum.

An incidental finding within the child/adolescent sample was the skewed age distribution of that smaller sample set, with 79% of the participants falling between the ages of 12-17. One possible conclusion for this finding may be related to maturation from childhood to adolescence. In particular, the residual effects from earlier childhood TBI (eg., ages 5-11) may not be fully appreciated until later in adolescent development when more complex learning and social contexts become more relevant. The findings of this study demonstrated that an average age of 14 on admission may reflect the interaction between normal development (eg., cognitive and social-behavioural advancement) and impairment (eg., lack of those skills) resulting from residual TBI injury. The impact of early deficits may not be fully appreciated until the 12-17 age range noted within this study. The child/adolescent group chronicity (time from injury to rehabilitation admission) was 39.9 months, which was considerably longer than all of the adult age ranges, suggesting a delay in receiving care. In particular for this subset, the difference in chronicity may be related to the delay in receiving services secondary to the delay appreciating the full range of residual injury deficits.

On the opposite end of the study specific to aging, older adults may be at higher risk for TBI because of age associated complications and conditions. Specifically, maturational changes in the aging brain initiate slow steady alteration in sensory awareness, balance, and information processing. As such, the risk of TBI due to falls and accidents increases with age [17]. Prior to the more recent research, age was considered a negative factor in benefitting from rehabilitation efforts. However, the current study found that those of advanced age were able to realize significantly improved disability at a similar level to those younger participants. In fact, when controlling for chronicity of injury and length of stay, each age group showed the same magnitude of improvement. Therefore, although age may present higher risks associated with TBI, age does not seem to play a role in reducing the benefits of treatment.

Therefore, options for continued reduction of disability following TBI across the age spectrum are necessary beyond the hospital level of care. Post-hospital care provides efficacious services for all age groups, and fills the gap in care from hospital to home.

Limitations of the Study

This study concluded at the time of program discharge from the various facilities. Long-term follow up is needed to evaluate the durability of the changes achieved in program, and specifically determine whether maintenance of skills is equivalent across the 6 age groups.

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