

RESEARCH ARTICLE

Effects of Fatigue, Driving Status, Cognition, and Depression on Participation in a Chronic Sample of Adults with Traumatic Brain Injury

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Abstract

Individuals with traumatic brain injury (TBI) often experience long-term participation restrictions. Physical and cognitive function, depression, age, ability to drive, and fatigue may contribute to participation restrictions post-TBI. The main objective of this study was to examine whether the ability to drive and fatigue contribute to participation among community-dwelling adults with TBI, after controlling for the age, cognition, and depression. We also explored the effects of these factors in a subgroup of participants who reporting clinically significant fatigue. This cross-sectional cohort study ($n=64$) included adults with moderate to severe TBI, ranging from 6 months to 38 years post-injury. We measured participation with the Participation Assessment with Recombined Tools, using Rasch-adjusted scoring. We measured physical and cognitive fatigue with the Rasch-adjusted scoring of the modified Fatigue Impact Scale. Participants self-identified their ability to drive (Yes/No). Hierarchical linear regressions revealed that driving status accounted for 4% of the variance in participation ($F_{1,59}\Delta=4.05$, $p=.049$, $R_{adj}^2\Delta=.038$), and fatigue accounted for 2% of the variance in participation ($F_{1,57}\Delta=1.77$, $p=.179$, $R_{adj}^2\Delta=.019$), after adjusting for age, depression, and cognition. The reverse was shown in the subgroup with clinically significant fatigue ($n=31$); driving status accounted for only 1% of the variance in participation ($F_{1,26}\Delta=0.71$, $p=.407$, $R_{adj}^2\Delta=.009$), whereas fatigue accounted for 15% of the variance in participation ($F_{1,24}\Delta=3.91$, $p=.034$, $R_{adj}^2\Delta=.150$). However, only physical fatigue, not cognitive fatigue, was a statistically significant independent predictor of participation. Depression, cognition, and ability to drive uniquely contributed to overall participation post-TBI. Among those with significant fatigue, depression and physical fatigue were the only significant predictors. The influence of personal and clinical factors on participation post-TBI may differ based on clinical symptoms an individual is experiencing. Personalized rehabilitation interventions selected based on clinical symptoms and targeting these modifiable factors could improve participation and quality of life for individuals with TBI.

Keywords

Traumatic brain injury, fatigue, participation, cognition, depression, driving

Introduction

The internationally accepted definition of “participation”, defined by the World Health Organization’s International Classification of Functioning, Disability and Health, is “involvement in a life situation”. “Participation Restrictions” are “problems an individual may



Open Access

Citation: Juengst SB, Osborne CL, Erler KS, Raina KD. Effects of Fatigue, Driving Status, Cognition, and Depression on Participation in a Chronic Sample of Adults with Traumatic Brain Injury. *Physical Medicine and Rehabilitation*. 2017; 1(1):4.

Received: September 23, 2017

Accepted: December 05, 2017

Published: December 10, 2017

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experience in involvement in life situations.”¹ Such broad definitions leave the concept of participation open for interpretation and dependent upon one’s perspective.² A synthesis of literature on the topic suggests that participation is characterized by “the extent to which social roles are fulfilled”.³ Investigators developed several instruments in an attempt to further operationalize the concept of participation. While these instruments differ by content and measurement scale, most contain three common domains: productivity, social relationships, and community involvement.² Therefore, we measured participation in community-dwelling individuals with traumatic brain injury (TBI) using the Participation Assessment with Recombined Tools-Objective (PART-O), a tool designed to examine long-term outcomes covering the most common domains of participation in individuals with TBI.²

Individuals with moderate to severe TBI experience long-term participation restrictions, including decreased social functioning.^{4–6} Participation is fundamental to the health and quality of life of individuals with TBI and considered an especially meaningful aspect of daily life by individuals with TBI, their family members, and the members of their healthcare team.^{7–9} Therefore, one of the primary goals of rehabilitation after TBI, and a prevailing indicator of successful functioning, is return to meaningful participation.^{10,11} In order to accomplish this goal, an understanding of the areas that most commonly impact one’s ability to engage in life situations after TBI is a crucial component of rehabilitation practice.

Previous literature identified many factors that contribute to participation after TBI, including physical and cognitive function, depression, age, ability to drive, and fatigue. Higher levels of functional independence, as measured by the FIM total and FIM subscale scores, were shown to be predictive of more participation up to 5 years after TBI.^{8,11,12} Individuals with depression or low positive affect (a hallmark of depression) demonstrated worse participation up to and after 5 years post-TBI.^{12–14} A recent investigation found that older age at time of injury predicted the trajectory of participation over the first 5 years after TBI, such that those who were older had worse participation that declined more quickly over time than those who were younger.¹² Older age has also been further associated with unemployment and inability to drive at 5 years post-TBI.¹⁵

Research has shown that driving cessation after TBI, even in the presence of access to alternative means of transportation, is associated with worse objective participation.^{16,17} In a large sample of community-dwelling adults 5 years post moderate to severe TBI, driving status uniquely contributed to participation and was a stronger predictor than cognitive or motor function (measured by the FIM™) or depression.¹⁸ Driving may be a fundamental component to participation in out of home activities. The constellation of potential cognitive, emotional, motor, or sensory impairments that can occur after TBI could limit the ability to safely execute the complex tasks required for driving. Novack and colleagues (2010) found that, at 5 years post moderate to severe TBI, only 53% of survivors of TBI return to driving.¹⁹ Of those individuals who returned to driving, less than half underwent professional evaluation of fitness to do so.²⁰

Chronic pathological fatigue has also been identified as a distressing symptom among 50–80% of individuals with TBI.^{21–24} Fatigue is distinct from other comorbid symptoms such as depression, pain, and disturbed sleep, and as such, interventions targeting these comorbid symptoms may not mitigate fatigue.^{25–27} While fatigue independently contributes to self-reported disability after TBI,²⁸ and a small number of studies suggest it could impact participation,^{29–31} its relationship to participation remains unclear. One study suggests that fatigue may not affect the frequency or quantity of participation,²³ but little is known about its impact on quality of participation. Additionally, fatigue is generally conceptualized and measured as a unidimensional construct. However, common fatigue measures having multiple subscales, including physical fatigue and cognitive fatigue,^{32–35} indicating multidimensionality. Particularly after neurological injury like TBI, individuals may experience differing levels of physical versus cognitive fatigue, though no studies to date have examined the effects of these individual domains on participation after TBI. Thus, the effects of fatigue on participation after TBI require further study.

The aims of the current study were to examine the extent to which ability to drive and fatigue (physical fatigue and cognitive fatigue) independently contribute to participation among community-dwelling adults with TBI, after controlling for age, cognitive function, and depression status. An additional exploratory aim was to examine whether fatigue has a stronger effect on participation among individuals experiencing clinically significant fatigue.

We hypothesized that both ability to drive and fatigue would independently contribute to participation after TBI and that fatigue would have a stronger effect on participation among those experiencing clinically significant fatigue.

Methods

Design

We collected data from a cross-sectional cohort study of adults who were living in the community with a history of moderate to severe TBI. The broader purpose of the study was to examine factors contributing to participation after TBI, so the present analyses falls under this scope.

Participants

A University Institutional Review Board approved all research procedures, and we obtained written informed consent from all participants or their identified proxies. Inclusion criteria were: 1) history of moderate to severe TBI; 2) ≥ 6 months post-injury; 3) living in the community; 4) > 18 years old. Moderate to severe TBI was defined as any injury acquired from an outside force to the head and resulting in a Glasgow Coma Scale (GCS)³⁶ score of 3-15 with positive neuroradiologic findings or sufficient functional compromise to require ongoing rehabilitative services. Exclusion criteria were: 1) comorbid condition resulting in progressive cognitive decline (e.g. dementia); 2) untreated psychosis or bipolar disorder; 3) current involvement in injury-related litigation.

Recruitment and Screening

We recruited participants through various sources, including: 1) the University of Pittsburgh's Rehabilitation Institute Research Registry; 2) existing research studies in the Departments of Physical Medicine & Rehabilitation and Occupational Therapy at the University of Pittsburgh; 3) local community and hospital-based support groups for individuals with TBI and their family members; 4) local organizations providing services to adults with TBI. We screened individuals who expressed interest in participation for inclusion to confirm TBI diagnosis, review demographic information, and for untreated mental health conditions. We confirmed TBI diagnosis through medical record review or confirmed participation in ongoing specialty rehabilitation service when medical records were not available, and we screened for psychosis and bipolar disorder using the Mood Primary Care Evaluation of Mental Disorders (PRIME-MD).³⁷

Measures

The first author collected all measures, meeting with participants in person at their place of residence or at a clinical facility of their choosing. Collected data included demographics (age, gender, race, education, driving status), injury-related characteristics (time since injury, injury severity), and clinical outcomes (functional disability, cognition, depression, fatigue impact, and participation).

Participation was measured using the Participation Assessment with Recombined Tools Objective (PART-O), a National Institute of Neurologic Disorders and Stroke Common Data Element for Participation after TBI.³⁸ The PART-O measures frequency of participation in activities in the home and community, including items related to productivity, social interaction and relationships, and getting out of the home.^{2,38,39} The present study used the Rasch-adjusted PART-O score derived from 11 items of the PART-O and representing a unidimensional scale for participation.⁴⁰ Scores range from 0–100.

Fatigue was measured using the modified Fatigue Impact Scale (mFIS), a tool that measures the impact of fatigue on everyday life in three dimensions that has been validated for use after TBI.^{32,33} The mFIS includes 21 items rated on a 5-point ordinal scale (0=no problem, 4=extreme problem) with references to the impact of fatigue over the past 4 weeks. Total scores range from 0-84, with higher scores indicative of greater fatigue. Scores > 38 indicate clinically significant fatigue.⁴¹ Rasch analysis of the mFIS in a sample with multiple sclerosis concluded that items represented two dimensions of fatigue: physical (8 items) and cognitive (5 items).³⁴ We used an mFIS score > 38 to determine participants for our subgroup analysis and used the Rasch-based Physical and Cognitive Fatigue scores to measure fatigue in our analyses.

Driving Status was measured through a single, self-reported question about whether or not

participants were currently able to drive.

Depression status was determined using the Patient Health Questionnaire (PHQ9), which assesses the nine diagnostic criteria for major depressive disorder.³⁷ Participants responded Yes or No to presence of each criterion nearly every day over the past two weeks. Participants were classified as having current depression if they endorsed one of the hallmark symptoms (e.g. depressed mood, lack of interest) and a minimum of 5 total symptoms.⁴² The PHQ9 is validated in moderate to severe TBI and is able to distinguish major depressive symptoms from the somatic and cognitive symptoms shared by both depression and TBI.^{42,43}

Functional Disability was measured with the Mayo Portland Adaptability Inventory (MPAI-IV), a 25-item measure of disability that captures abilities, adjustment, and participation.^{44,45} Items are rated on a 0–4-point ordinal scale (0=no problem, 4=severe problem), and a *t*-score (mean=50, *SD*=10) is derived from the total score. Higher *t*-scores indicate greater disability.

Cognitive function was measured using a composite *t*-score derived from a brief neuropsychological test battery validated within the TBI Model Systems national database study.⁴⁶

This battery provided an overview of cognition in the cognitive domains most commonly affect by TBI. We included six of the eight neuropsychological tests from the validated battery, deemed most appropriate for a community-based sample. We calculated an overall Cognitive composite *t*-score by averaging relevant *t*-scores from each test, summarized below.

California Verbal Learning Test II (CVLT-II) is a 16-item list-learning task that incorporates learning, short-term delayed recall, long-term delayed recall, and long-term delayed recognition.⁴⁷ The adjusted *t*-score for learning (total trials 1–5) contributed to the Cognitive Composite score in this study.

Trail Making Test (TMT) is a timed test to measure visuoconceptual and visuomotor tracking.⁴⁸ Participants connect sequential dots of numbers (Trails A) and alternating numbers and letters (Trails B) as quickly as they correctly can. Times to complete Trails A and Trails B were each converted to adjusted *t*-scores based on published norms, and both contributed to the Cognitive Composite *t*-score.

Symbol Digits Modalities test (SDMT) is a brief measure of visual perceptual skills, scanning, and psychomotor speed.⁴⁹ The total written score on the SDMT was converted to an adjusted *t*-score and used in the Cognitive Composite *t*-score.

Letter and Category Fluency (FAS/Animal Naming) assesses generativity and executive functioning by asking participants to name as many words as they can that begin with a certain letter (F-A-S) and to name as many different animals as they can (Animal Naming) in 60 seconds.⁵⁰ Total fluency scores for FAS and for Animal Naming were converted to adjusted *t*-scores based on published norms, and both contributed to the Cognitive Composite score.

Wisconsin Card Sorting Test (WCST) 64-item version assesses executive functions through a card sorting activity that requires cognitive flexibility and problem solving.^{51,52} The adjusted *t*-score for total perseverative errors contributed to the Cognitive Composite score.

Analyses

We analyzed data with SPSS 24.0 for Windows. First, we examined descriptive statistics to characterize the sample. Next, we conducted Spearman correlations to demonstrate relationships among our variables of interest. Last, we conducted three consecutive linear regressions (e.g. hierarchal regressions) to test our hypotheses that driving status and fatigue would each independently contribute to participation after controlling for cognitive impairment, depression status, and age. The first model (Model 1) included all covariates *except* driving status and fatigue. The second regression (Model 2) added driving status to the model. The final regression (Model 3) added fatigue (mFIS Physical and Cognitive subscales) to the model. The change in R^2 values between each model represented the individual contribution of driving status and fatigue to participation, after controlling for the other covariates. We assessed model diagnostics to ensure good model fit, including variance inflation factors and tolerance.

To address our exploratory aim, we ran the hierarchical linear regressions again, this time only in a sample of participants with clinically significant fatigue. Again, the change in R^2 values between each model represented the individual contribution of driving status and fatigue to participation, after controlling for the other covariates, and we assessed the same

model diagnostics to ensure good model fit.

Results

Descriptive

Sixty-four participants completed the study. Table 1 summarizes the descriptive data for this study. For the full cohort, time since injury ranged from 6 months to 38 years, with a median time of ~5.5 years. Age ranged from 18 to 86 years old, and education ranged from 10 years (e.g. some high school) to 20 years (e.g. PhD or MD). Participants reported a mean standardized disability score within an average range, with a trend towards less disability than average ($M=44.3$, $SD=13.1$). The mean fatigue score on the mFIS fell just below the threshold for clinically significant fatigue,⁴¹ though it ranged from no fatigue (0) to severe fatigue (77). Cognition showed a similarly wide range, with t -scores as low as -1.3 and as high as 59.2 (<40 indicates cognitive impairment), though on average were within the range for normal cognition. Thirty-one participants (48%) reported clinically significant fatigue. As expected, the subgroup reported more fatigue than the full cohort, and also reported slightly more disability and depression. All other factors were generally comparable.

Correlations

Table 2 reports the Spearman correlation coefficients for all variables. Rasch-adjusted PART-O scores were significantly correlated ($p's < .05$) Physical fatigue, Cognition, Depression status, and Driving Status. Cognitive fatigue did not significantly correlate with the PART-O, though Cognitive fatigue and Physical fatigue were highly correlated ($r=.809$, $p < .01$).

Table 1. Participant Characteristics

	Full Cohort (n=64) Mean (\pm SD)	Fatigue Subgroup (n=31)* Mean (\pm SD)
Age (years)	45.9 (\pm 16.5)	49.3 (\pm 15.8)
Time Since Injury (months)	55.0 (13.5-104.5) [†]	59.0 (14.0-148.0) [†]
Education (years)	14.6 (\pm 2.6)	14.3 (\pm 2.4)
Disability - MPAI (t-score) [‡]	44.3 (\pm 13.1)	51.4 (\pm 6.9)
Fatigue – mFIS (total) [‡]	36.0 (\pm 21.1)	54.3 (\pm 9.9)
Physical Fatigue (mFIS subscale) ^{**}	14.4 (9.5)	22.4 (4.1)
Cognitive Fatigue (mFIS subscale) ^{**}	8.1 (5.3)	12.3 (3.5)
Cognitive Composite score (t-score)	44.5 (\pm 12.0)	44.2 (\pm 7.3)
Participation (PART-O) ^{**}	56.2 (\pm 5.9)	55.3 (\pm 5.2)
	n (%)	n (%)
Gender (male)	51 (80%)	23 (74%)
Race (white)	62 (97%)	30 (97%)
Ability to drive (yes)	44 (69%)	22 (71%)
Injury Severity		
Moderate	33 (51%)	16 (51%)
Severe	31 (48%)	15 (48%)
Depression status (current depression)	9 (14%)	6 (19%)

* Subgroup: Participants with significant fatigue (mFIS>38); †Median and interquartile range; ‡ Higher scores indicate poorer outcomes; **Scores based on Rasch analysis of measurement tool; MPAI=Mayo Portland Adaptability Inventory; mFIS=modified Fatigue Impact Scale; PART-O=Participation Assessment with Recombined Tools Objective

Table 2. Spearman Correlations (n=64)

	Physical Fatigue	Cognitive Fatigue	Cognition	Depression Status	Driving Status	Age Group
Participation (Rasch-adjusted PART-O)	-.260*	-.174	.270*	-.299*	.304*	-.110
Physical fatigue (mFIS subscale)		.809†	-.082	.226	-.005	.224
Cognitive fatigue (mFIS subscale)			-.099	.177	.060	.040
Cognition (Cognitive Composite T-score)				.026	.402†	.037
Depression status (Y/N)					-.022	-.105
Driving status (Y/N)						.028
Age Group						

*mFIS subscales are based on Rasch-adjusted scales. The Physical fatigue subscales contains the two items on the original psychosocial subscale of the mFIS. Age groups are 18-24, 24-59, 60+ years old. * $p < .05$; † $p < .01$; 2-tailed correlations

Table 3. Hierarchical Linear Regression Analyses for the Effects of Driving and Fatigue on Participation (n=64)

Participation			Participation			Participation		
Model 1			Model 2			Model 3		
β_{stand}	P		β_{stand}	P		β_{stand}	P	
Intercept	-	<.001	Intercept	-	<.001	Intercept	-	<.001
Age	-.210	.069	Age	-.200	.077	Age	-.173	.151
Cognitive Impairment	.386	.001	Cognitive Impairment	.270	.034	Cognitive Impairment	.275	.029
Depression Y/N	-.334	.004	Depression Y/N	-.320	.005	Depression Y/N	-.277	.019
			Driving Status Y/N	.247	.049	Driving Status Y/N	.251	.044
						Physical Fatigue	-.077	.693
						Cognitive Fatigue	-.143	.438
$R^2=.250$			$R^2=.299$			$R^2=.340$		
$R^2_{\text{Adj}}=.213$			$R^2_{\text{Adj}}=.251$			$R^2_{\text{Adj}}=.270$		
			$R^2\Delta= .048$			$R^2\Delta= .041$		
			$R^2_{\text{Adj}}\Delta= .038$			$R^2_{\text{Adj}}\Delta=.019$		

(with driving added as a covariate). Fatigue alone accounted for 2% of the variance in participation ($F_{1,57}\Delta=1.77$, $p=.179$, $R_{adj}^2\Delta=.019$) based on the change in the R_{adj}^2 value from Model 2 (without fatigue as covariates) to Model 2 (with fatigue added as a covariate). However, fatigue did not meet the threshold for statistical significance.

Based on the standardized betas in Model 3, cognition and depression ($|\beta|s=.28$) were the strongest predictors of participation, followed by ability to drive ($\beta=.25$). With regard to model diagnostics, the variance inflation factor ranged from 1.12 to 3.25, indicating moderate correlations among covariates, and the tolerance ranged from .30 to .89, indicating no problem with multicollinearity.

Exploratory Analyses: Subgroup of Participants with Clinically Significant Fatigue

Table 4 reports the Spearman correlation coefficients for all variables in the subgroup ($n=31$). Rasch-adjusted PART-O scores were significantly correlated ($p's<.05$) Physical fatigue and Depression status only. Unlike in the full cohort, Cognitive fatigue and Physical fatigue did not significantly correlate in the subgroup.

Table 5 summarizes results from the exploratory regression analyses. Overall, fatigue, driving status, cognition, depression, and age together explained 33% of the variance in participation among adults with clinically significant fatigue after TBI ($F_{6,24}=3.44$, $p=.013$, $R_{adj}^2=.328$). Driving status alone accounted for only 1% of the variance in participation ($F_{1,26}\Delta=0.71$, $p=.407$, $R_{adj}^2\Delta=.009$) and was not statistically significant. Fatigue alone accounted for 15% of the variance in participation ($F_{1,24}\Delta=3.91$, $p=.034$, $R_{adj}^2\Delta=.150$). Based on the standardized betas in Model 3, Depression ($\beta=-.39$) and Physical fatigue ($\beta=-.38$) were the strongest predictors of participation. Though fatigue overall contributed 15% of the variance in participation, only Physical fatigue, and not Cognitive fatigue, was a statistically significant independent predictor of participation. With regard to model diagnostics, the variance inflation factor ranged from 1.27 to 1.53, indicating low moderate correlations among covariates, and the tolerance ranged from .67 to .84, indicating no problem with multicollinearity.

Table 4. Spearman Correlations in Subgroup with Clinically Significant Fatigue ($n=31$)

	Physical Fatigue	Cognitive Fatigue	Cognition	Depression Status	Driving Status	Age Group
Participation (Rasch-adjusted PART-O)	-.458*	-.262	.125	-.471†	.169	.244
Physical fatigue (mFIS subscale)		.311	.201	.165	-.092	-.110
Cognitive fatigue (mFIS subscale)			-.038	.032	.044	-.366*
Cognition (Cognitive Composite T-score)				.164	.461†	.120
Depression status (Y/N)					-.046	-.242
Driving status (Y/N)						.281
Age Group						

*mFIS subscales are based on Rasch-adjusted scales. The Physical fatigue subscales contains the two items on the original psychosocial subscale of the mFIS. Age groups are 18-24, 24-59, 60+ years old. * $p<.05$; † $p<.01$; 2-tailed correlations

Table 5. Hierarchical Linear Regression Analyses for the Effects of Driving and Fatigue on Participation in Subgroup with Clinically Significant Fatigue (n=31)

Participation			Participation			Participation		
Model 1			Model 2			Model 3		
β_{stand}	P		β_{stand}	P		β_{stand}	P	
Intercept	-	<.001	Intercept	-	<.001	Intercept	-	<.001
Age	.132	.454	Age	.100	.579	Age	.015	.934
Cognitive Impairment	.182	.300	Cognitive Impairment	.103	.603	Cognitive Impairment	.219	.241
Depression Y/N	-.460	.013	Depression Y/N	-.445	.017	Depression Y/N	-.389	.026
			Driving Status Y/N	.166	.407	Driving Status Y/N	.093	.621
						Physical Fatigue	-.378	.035
						Cognitive Fatigue	-.156	.371
$R^2=.268$			$R^2=.288$			$R^2=.463$		
$R^2_{\text{Adj}}=.187$			$R^2_{\text{Adj}}=.178$			$R^2_{\text{Adj}}=.328$		
		.035			.058			.013
			$R^2\Delta=.019$			$R^2\Delta=.175$		
			$R^2_{\text{Adj}}\Delta=.009$.407		$R^2_{\text{Adj}}\Delta=.150$.034

Note. $R^2\Delta$ for Driving Status ($F_{1,26}\Delta=0.710$, $P=0.407$); $R^2\Delta$ for Physical and Cognitive Fatigue ($F_{1,24}\Delta=3.909$, $P=0.034$); . "No" is referent group for depression and driving status

Discussion

This investigation into the independent contributions of driving ability and fatigue on participation after TBI corroborates the small body of previous literature on post-TBI participation, but also raises new questions as to the ability to apply findings of this nature to individuals with TBI as a whole. Our work supports the effect of driving on participation and the idea that fatigue does not contribute to frequency of participation in community-based activities. However, we found the reverse when looking only in a subgroup of individuals with TBI who are experiencing notable fatigue. Driving did not influence participation, and Physical fatigue was one of the strongest contributing factors. This suggests that the influence of personal and clinical factors on participation post-TBI may differ based on clinical symptoms an individual may be experiencing.

Although more than half of individuals with TBI return to driving by 5 years post injury, there is limited literature examining the association of driving with participation.¹⁹ The few studies that exist have found that individuals who drive have better participation and social outcomes than non-drivers.^{16–18} This study provides further evidence that individuals who return to driving after TBI have a higher frequency of participation. The items on the PART-O that involve activities happening outside of the home (e.g. eating in restaurants, going to the movies, or shopping) are those most likely to occur more frequently as a result of driving. Interestingly, driving was not a significant contributor to participation for individuals with TBI who were also experiencing notable fatigue. Perhaps, these individuals are distinct in that they have been forced to develop additional coping and compensatory strategies to complete tasks outside of the home in the setting of clinically significant fatigue. These individuals may include a prioritization system as a part of energy conservation techniques such as choosing to shop online instead of a store in order to be able to have the energy to attend religious activities outside of the home. Although the Rasch-adjusted PART-O scores for this subgroup were similar to those without clinically significant fatigue, another possible explanation is that they are participating more in activities that occur within the home and limiting activities outside of the home, while those without clinically significant fatigue may have more of a balance

between in and out of home items. Future research should compare within the home versus outside the home participation between those with clinically significant fatigue and those without it to test this hypothesis. While one scoring algorithm for the PART-O has a subscale for “Out and About”,² there is no comparative subscale for within the home participation. Future studies should also examine the association of driving status with quality of participation and satisfaction with participation.

Only a small body of evidence exists for the impact of fatigue on participation after TBI. Among adults with chronic TBI, fatigue independently predicted disability,²⁸ as measured by the MPAI-IV, which does contain a validated subscale for participation.⁴⁴ However, this small study did not investigate participation specifically. Another study found no association between fatigue and frequency of participation post-TBI, but did find that fatigue was highly associated with quality of life.²³ This led the authors to suggest that fatigue may influence quality of participation, rather than frequency of participation in major life activities.²³ In our study, we measured participation using the PART-O, which measures frequency of participation and not quality of participation. For example, individuals may report that they are engaging in homemaking activities 35 or more hours per week (a high frequency of participation), but compared to before injury when they were preparing full course meals and cleaning the house every day, they are now only preparing cold sandwiches and cleaning one room of the house each day. Similarly, individuals may report that they socialize with friends 10-19 times per week, but this does not differentiate whether they are having long, meaningful conversations with friends or whether they are only able to socialize for 20 minutes at a time in order to effectively conserve energy.

Our study does suggest that, among those experiencing high levels of fatigue, their Physical fatigue (but not cognitive fatigue) may influence their frequency of participation. At a certain point, physical fatigue may put a ceiling on the number or amount of certain activities that a person can accomplish or engage in. Cognitive fatigue did not show a similar relationship; it could be that individuals may continue to be able to engage in certain activities despite cognitive fatigue, though again, the quality of their engagement may diminish as a result. It is possible that individuals experiencing significant fatigue do not differentiate well between physical and cognitive fatigue, hence perceiving and reporting the effects of fatigue on physical activities and not the effects of fatigue on cognitive functions. Overall, the impact of fatigue on participation may differ based on severity and nature (e.g. physical, cognitive) of the fatigue experienced and by dimension of participation (e.g. frequency, quality, satisfaction).

This study supports the growing body of literature post-TBI indicating that frequency, quality, and satisfaction are distinct dimensions of participation.^{14,23,53–55} The notion that participation is multi-dimensional is consistent with the theoretical foundation of the ICF framework. Complex interactions between ICF components are not always a predictable one-to-one relationship and influence an individual's experiences and perception of those experiences. A person's physical, mental, emotional, and environmental characteristics are perpetually interacting in new ways, which continuously alters ability and/or desire to participate in the surrounding world.⁵⁶ The results of this study contribute to a more comprehensive understanding of the complexities of participation after TBI, specifically the influences of driving and fatigue, as defined by the ICF theoretical model.

The strongest predictors of participation among adults with chronic TBI in our study were cognitive impairment and depression. This is consistent with previous studies on participation after TBI.^{5,12,14,57,58} Of note, however, is that among those with high levels of fatigue, cognitive impairment was not associated with participation, despite comparable cognitive composite and participation scores between the full cohort and the subgroup with high fatigue. In these individuals, the experience of fatigue – particularly physical fatigue – may be so distressing that it replaces cognitive impairment as the predictor of frequency of participation. This is notable as it has implications for intervention. First, measuring and addressing fatigue as a multidimensional construct (e.g. looking at both physical and cognitive fatigue separately and in conjunction) may yield a more complete and specific characterization of an individual to inform intervention. Second, for individuals with significant chronic fatigue after TBI, management of fatigue should be the primary target of intervention.

Study Limitations

This study was a secondary analysis of existing data from a cross-sectional cohort study.

Participants were not representative of all community-dwelling adults with a history of TBI, particularly with regard to racial and ethnic diversity. Men were also over-represented in this sample, even given the higher percentage of men among those sustaining a TBI. The measures used in this study, other than for cognition, were self-reported, so recall bias or poor self-awareness may have influenced the study results. However, despite the limitations of self-reported measures, it is still the most feasible – and sometimes the most appropriate – method of data collection for studies answering questions of this nature. Development of a cut-off score for clinically significant fatigue in a moderate to severe TBI sample, particularly using the Rasch-adjusted mFIS subscale scores (e.g. physical fatigue, cognitive fatigue) is warranted. The heterogeneity of the sample, with regard to age, time since injury, cognition, fatigue, and participation, was both a strength and a limitation. It reduced our statistical power while simultaneously increasing our ability to generalize more broadly to the TBI population. Large longitudinal studies would be better able to examine the effects of chronicity of injury and age, and the interplay between the two, on participation. Though challenging in a community-based sample, it would be beneficial to have a more thorough characterization of the initial injury, including loss of consciousness, length of post-traumatic amnesia, location of injury, extra-cranial injuries, etc. Finally, we looked only at driving status and not more broadly at independent transportation. Future research should examine these relationships in a larger heterogeneous sample, with better racial, ethnic, gender, and geographic diversity.

Conclusions

Depression, cognition, and ability to drive uniquely contribute to overall participation among community-dwelling adults with a history of moderate to severe TBI. Among the subgroup with clinically significant fatigue, depression and physical fatigue are the only significant predictors. This suggests that the influence of personal and clinical factors on participation post-TBI may differ based on clinical symptoms an individual may be experiencing. Personalized rehabilitation interventions, selected based on clinical symptoms and targeting these potentially modifiable factors, could improve participation and subsequently improve quality of life for individuals with TBI.

Funding

This study was supported in part through funding received from the School of Health and Rehabilitation Science Research Development Fund, School and Health of Rehabilitation Science, University of Pittsburgh (SJ); by the National Institutes of Health Clinical Loan Repayment Program NICHD L30 NS089099-02 (SJ), and by the U.S. Army Medical Research and Materiel Command under Award No. W81XWH-10-1-0920 (KR, SJ). Opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the U.S. Army.

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