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RESEARCH PAPER

Prediction of long-term occupational performance outcomes for adults after moderate to severe traumatic brain injury

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Abstract

Purpose. To examine predictors of long-term occupational performance outcomes for adults after moderate to severe traumatic brain injury (TBI).

Method. This study involved analysis of data from a retrospective cohort of adults ($N = 306$) with moderate to severe TBI discharged from a Pennsylvania rehabilitation treatment facility. Extensive pre-injury sociodemographic, injury-severity, post-injury personal (cognitive, physical, affective), post-injury environmental (social, institutional, physical), and post-injury occupational performance (participation in self-care, productivity, leisure activities) data were gathered from hospital records and using in-person interviews. Interviews occurred at a mean time of 14 (range, 7–24) years post-injury. Hierarchical multiple regression analysis was used to investigate determinants of long-term occupational performance outcomes.

Results. Pre-injury behavioural problems, male gender, post-injury cognitive and physical deficits, and lack of access to transportation were significant independent predictors of worse occupational performance outcomes.

Conclusions. The study supports the use of a comprehensive model for long-term outcomes after TBI where pre-injury characteristics and post-injury cognitive and physical characteristics account for the greatest proportion of explained variance.

Keywords: *Traumatic brain injury, ageing, occupational performance, long-term outcomes, prediction*

Introduction

Advances in emergency medicine and technology have contributed to a growing number of persons surviving moderate to severe traumatic brain injury (TBI). As cohorts of persons with TBI grow older, information is needed on predictors of long-term outcomes, particularly because it has been hypothesized that normal age-related changes may compound problems that already exist because of the TBI [1].

One important long-term outcome following TBI is occupational performance. Occupational performance is a term unique to the profession of occupational therapy and is defined as the 'ability to choose and satisfactorily perform meaningful occupations that are culturally defined and appropriate for looking after one's self (self-care), enjoying life (leisure), and contributing to the social and economic fabric in a community (productivity)' (p. 45) [2]. From a clinical perspective, occupational performance is an important outcome because a primary goal of rehabilitation is to assist persons with TBI to return to active and purposeful roles and activities in the community. However, numerous studies have shown that community dwelling adults with TBI continue to experience significant limitations in the occupational performance domains of self-care, productivity, or leisure many years post-injury [3–21]. In order to target

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rehabilitation efforts aimed at maximizing the occupational performance of adults post-TBI, information is needed on predictors of long-term occupational performance outcomes. In addition, this research could be used to help guide the development of models of ageing with TBI and policy actions aimed at supporting the needs of persons ageing with TBI.

A literature search was conducted to identify long-term TBI outcome studies whose main outcome of interest was conceptually similar to the construct of occupational performance. The search, restricted to studies using bivariate or multivariate regression analyses, follow-up periods of a minimum of 5 years post-TBI, and samples of primarily moderate to severe TBI, resulted in the identification of 14 studies [5,19,22–33]. Long-term TBI outcome studies have traditionally grouped variables of interest into three principal classifications: pre-injury-related factors (e.g. sociodemographic), injury-related factors (e.g. injury severity), and post-injury-related factors (categorized into those at the level of the person and at the level of the environment) [22].

With regard to pre-injury sociodemographic predictors, although results vary, there are some consistent findings with male gender [23], older age at injury [24,25] fewer number of years of education [24,26], and employment at injury (unemployed) [19,25,27] predicting worse occupational performance outcomes. A number of studies have shown that pre-injury related factors such as longer durations of loss of consciousness (LOC) [24,25,28], post-traumatic amnesia [24,25,28], and length of stay (LOS) [19,24–26] predict worse outcomes, primarily in the domains of self-care and productivity. With regard to post-injury personal variables, there appears to be agreement with respect to the influence of cognitive and physical function on long-term outcomes with lower levels of cognitive [19,23,25,29] and physical [5,23,29,30] function predicting worse occupational performance outcomes. There is less agreement with respect to the influence of affective function (e.g. emotional health, self-esteem) [23,29] and duration of injury [24,29,31] on long-term outcomes; however, these variables have been studied to a lesser extent. In addition, variation on lengths of follow-up varied across studies, which may affect these results. Only four of the 14 studies examined post-injury environmental factors in relation to occupational performance outcomes. Physical environmental barriers were associated with worse occupational performance outcomes in one study [5]. Three studies examining aspects of the social environment (e.g. social support) in relation to occupational performance outcomes failed to find any significant associations [22,30,32].

The review of the literature identified several gaps that are important to consider in future research. First, the majority (nine of the 14) of studies had mean follow-up periods of less than 10 years, and the average age of study participants was less than 60 years of age. There is a need for studies to examine outcomes of longer durations (i.e. greater than 10 years post-injury) and with broader age ranges (i.e. greater than 60 years of age). In particular, it may be important to explore the influence of duration of injury and chronological age on post-injury function given the potential for the compound effect of normal age-related changes over time.

Second, the inclusion of important environmental factors was largely absent from the studies reviewed, despite calls for further research on the influence of environmental factors [5,23,30,34]. Reasons for the lack of focus in this area could be attributed to a lack of conceptual frameworks focusing on the environment or an absence of standardized tests to measure broad aspects of the environment.

Third, with regard to the use of conceptual frameworks, it was discovered that only four of the 14 studies utilized an explicit framework to guide the study. The earlier version of the International Classification of Functioning, Disability, and Health (ICF), the International Classification of Impairment, Disability, and Handicap (ICIDH), was used in three studies [5,23,33], and the Wood-Dauphinee and Kuchler model of health related quality of life was used in the fourth [30]. The utilization of explicit conceptual frameworks leads to a more comprehensive selection of variables and provides insight into how these variables relate to outcome.

The purpose of the present study was to examine predictors of long-term occupational performance outcomes for adults following moderate to severe TBI. The specific objectives were (1) to examine the main and interaction effects of chronological age and duration of injury on long-term outcomes in the domains of occupational performance; and (2) to examine the association between pre-injury sociodemographic, injury-related, post-injury personal, and post-injury environmental variables and post-injury occupational performance outcomes in order to understand determinants of long-term outcomes. The main hypothesis of this study was that older age and a longer duration of injury would be independently associated with worse occupational performance outcomes after controlling for the impact of other variables and that the interaction of chronological age and duration of injury would limit domains of occupational performance to a greater degree than either factor would independently. These hypotheses were based on the assumptions that normal age-related changes [35] may compound problems that already exist because of the TBI and that living with a TBI for a long period of time places increased stress and demands on the person.

Methods

Participants and procedure

This study involved analysis of data from a retrospective cohort study of adults ($N = 306$) with moderate to severe TBI discharged from a rehabilitation treatment facility in Pennsylvania. Specific sampling and data-collection procedures have been previously reported [36,37]. Briefly, participants were included if they had International Classification of Disease [38] codes for head injury that comprise skull fractures and intracranial injuries. In addition, participants had to be at least 14 years of age at the time of injury and live within a 150-mile radius catchment area from the project office in Pittsburgh. Individuals who had a spinal cord injury in addition to a head trauma were excluded because they represented a distinct group.

The review of medical records resulted in 642 eligible participants. Six hundred (93%) eligible participants were traced, of which 128 (20%) were deceased, and 82 (12.7%) were not within the specified catchment area for home interviews. Individuals who were deceased were older at the time of injury (mean age of 55.5 years vs. 30.1) and had lower injury-severity scores as measured by the Injury-Severity Scale (ISS) [39] compared to the respondents (mean of 20.8 vs. 26.3). Of the remaining 390 participants who were eligible for an interview, 52 (13.3%) refused, and 30 (7.7%) were lost to follow-up. There was no statistically significant difference ($p < .05$) between participants and those who refused or were lost to follow-up with respect to gender, education, marital status, or injury severity (as measured by LOC or the ISS). However, there was a tendency for non-participants to be male, to have fewer years of education, and to be divorced or separated at the time of injury. Trained individuals with bachelor or master level degrees conducted all interviews. The majority of participants were interviewed in their home. A small percentage of interviews were completed by telephone at the participant's request.

Conceptual framework

Figure 1 illustrates the conceptual framework for this study with each of the variables selected for analyses assigned to its conceptual category. This framework is primarily based on existing models of occupational performance [2], however it has been modified to include pre-injury and injury-related factors because of their significance in TBI outcomes research and because they are not explicitly operationalized in models of occupational performance. Pre-injury factors in this framework include sociodemographic variables; injury-related factors include indicators of injury-severity; and post-injury factors include personal, environmental, and occupational performance variables. Independent variables were selected based on the conceptual framework, the literature review, and the available variables in the data set. In addition, an attempt was made to include parameters suggested by Rappaport et al. [16] to help structure the description of the sample and to facilitate meaningful comparisons between studies. In this framework, the person is viewed as having physical, cognitive, and affective domains as TBI has been shown to affect all aspects of a person's functioning. The environment is viewed broadly to include social, physical, and institutional aspects. The top arrow depicts the influence of pre-injury and injury-related factors on post-injury factors, representing the temporal relationships in the framework. Finally, occupational performance is the dependent variable in this conceptual framework and is hypothesized to occur because of the interaction among the independent variables: pre-injury sociodemographic, injury-related, post-injury personal, and post-injury environmental.

Independent variables

Pre-injury sociodemographic factors. Data on age, gender, marital status, education, employment, and behavioural problems were abstracted from the medical records and included in the follow-up interview if this information was not recorded in the medical records. To provide a more parsimonious approach to the analyses, pre-injury variables were coded as follows. Marital status was categorized as married or living with someone and not married or not living with someone. Information on education was based on the number of years of education completed at time of injury (counting from grade one). Employment was operationalized to include two categories: unemployed or retired and employed or homemaker or student. Information related to prior alcohol and/or substance abuse problems, prior problems with the law, and prior psychiatric problems was collapsed into two categories: no problems with alcohol or controlled substances or law or psychiatric and problems with alcohol or controlled substances or law or psychiatric.

Injury-related factors. The process of abstracting data from the medical record to calculate the Injury Severity Score and LOC is described in detail in an earlier publication [36]. Information on LOC was categorized as less than 24 h, 1 day to 1 week, greater

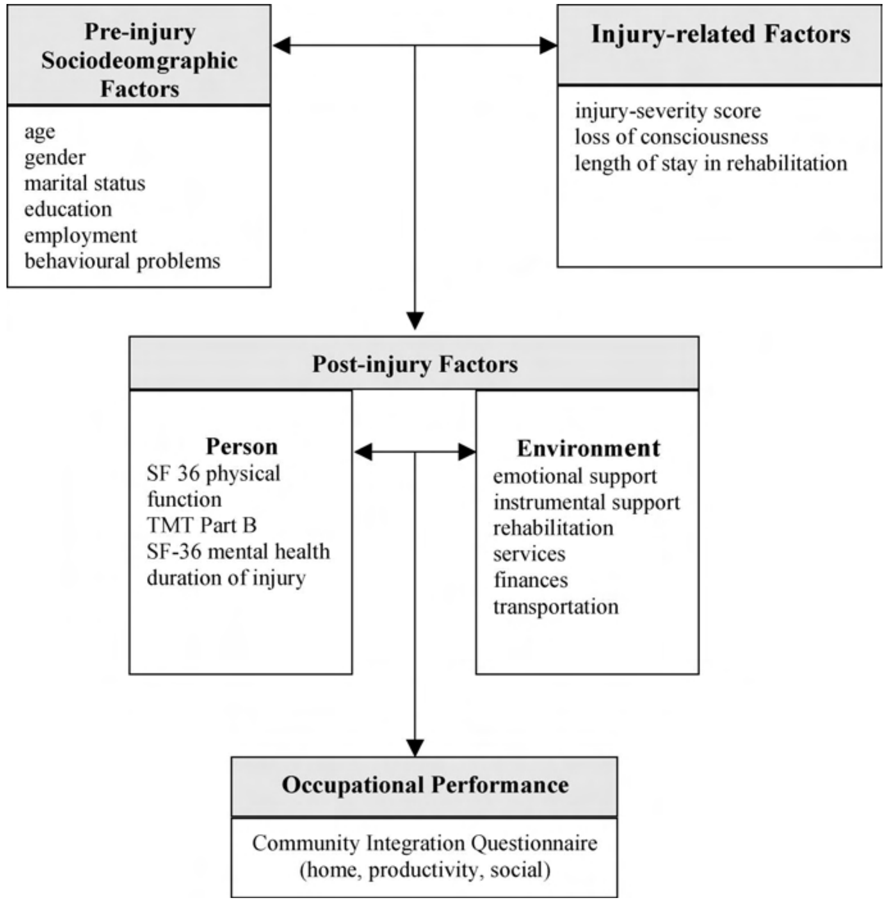

Figure 1. Conceptual framework.

than 1 week to 4 weeks, and greater than 4 weeks. These categories represent hours, days, weeks, and months, as has been done in previous TBI long-term outcome studies [24,28]. Dummy variables were created for the multiple regression analysis using less than 24 h as the reference category. Data were missing for 20.3% of the LOC variables; however, it was not possible to determine appropriate values to impute. Rehabilitation LOS was measured in days and calculated based on recorded admission and discharge dates to the rehabilitation hospital. Rehabilitation LOS was chosen over acute LOS or total LOS in acute and rehabilitation settings to facilitate comparison with other studies and to focus on duration of time in rehabilitation as an indicator of long-term outcome.

Post-injury personal factors. The Physical Function subscale of the Medical Outcomes Study Short Form-36 (SF-36) [40] was used as a measure of physical status at time of follow-up. The Physical Function subscale consists of 10 items (e.g. walking, climbing stairs, and lifting heavy objects). The subscales are scored by summing the raw scale scores and transforming raw scores to a 0–100 scale (higher scores indicate higher levels of physical function). In a sample of persons with moderate to severe TBI, internal consistency for the SF-36 subscales ranged from 0.79 to 0.92 (Cronbach's alpha), and significant correlations were found between the Physical Function subscale of the SF-36 and the Physical scale of the Institute for Rehabilitation Research Symptom Checklist ($r = -0.41$, $p < .01$) and Health Problems List (-0.40, $p < .01$) [41].

A cognitive battery was administered at the time of follow-up and included the Trail Making Test (TMT), Parts A and B [42]. The TMT tests attention, sequencing, mental flexibility, visual search, and motor function [43]. The time to completion score on the TMT, Part B was selected as the primary measure of residual cognitive deficits for the present study, as it has been shown to be more sensitive to brain damage than the TMT, Part A or the performance errors score [43–45]. The TMT, Part B entails drawing a line to connect 13 randomly arranged numbers and 12 letters, alternating between numbers and letters in a sequential manner. The time to complete the test is measured in seconds (maximum time allowed is 300 s) with shorter times reflecting a better score. The psychometric properties of the TMT are well established and have been studied extensively in samples of persons with brain injury [43]. In the case of the TMT, Part B, 21 participants were untestable because of the severity of their cognitive deficits. In these cases, it was deemed appropriate to award them the worst possible score (300 s) on the TMT, Part B.

The Mental Health subscale of the SF-36 was used as a measure of affective status at time of follow-up. This subscale consists of five items, which are intended to reflect emotional or feeling states (e.g. feeling depressed, worn out, tired). Scores range from 0 to 100, with higher scores indicating higher levels of emotional well-being. The Mental Health subscale has been found to have a high internal consistency (Cronbach's alpha above .85) in a sample of persons with chronic health conditions [46,47]. In a sample of persons with moderate to severe TBI, Findler et al. [41] reported significant correlations between scores on the SF-36 Mental Health subscale and the Beck Depression Inventory ($r = -0.60$, $p < .01$).

The duration of injury variable was calculated by subtracting the date of the follow-up interview and the date of the injury, and rounding to the nearest year.

Post-injury environmental factors. Emotional and instrumental (i.e. help with daily tasks) support were selected as indicators of social support and operationalized by asking participants if they could rely on anyone if they needed emotional or instrumental support. Two variables were used to operationalize institutional aspects of the environment: spectrum of rehabilitation services and adequacy of finances. Participants were asked if they received any rehabilitation services including occupational therapy, physical therapy, speech and language therapy, or chiropractic therapy for their TBI since discharge from the rehabilitation hospital. For each therapy, participants answered yes or no as to whether the service was received. The total number of services for each participant was derived from the yes or no responses to facilitate ease of analysis. Adequacy of finances was measured using an item derived from the London Handicap Scale [48]. Participants were asked their ability to afford things in the context of whether health problems led to any extra expenses or to less earning potential. For the purpose of analysis, the original six-point scale was collapsed into two categories: easily or fairly easily able to afford things, and absolutely not or less easily able to afford things.

The physical domain of the environment was operationalized using questions related to availability of and access to transportation. Participants rated whether their current transportation arrangement allowed them to get to all the places they would like to go and to get out whenever they wanted. These two variables were collapsed into two categories: access or availability to transportation and no access or availability to transportation.

Dependent variable

The Community Integration Questionnaire (CIQ) [49], administered at follow-up, was used to operationalize the dependent variable: occupational performance. For the purpose of this study, it is proposed that the three domains of occupational performance (i.e. self-care, productivity, leisure) are conceptually similar to those of the CIQ (i.e. home integration, productivity, social integration). The CIQ consists of 15 items, measured on an ordinal scale, which produce a composite total score ranging from 0 to 29 with higher scores indicating a better occupational performance. Scoring is based on the frequency and level of independence in performing specific activities or roles within the home or community. The CIQ was scored using the original system of scoring instead of the revised system proposed by Sander et al. (1999) [50]. Using the original scoring system allowed for comparison with previously published data, since the revised system has not yet been widely adopted. The psychometric properties of the CIQ have been supported in several studies [23,49,51–57]. Others [58] have proposed that the CIQ can be utilized as a measure of occupational performance, even though the CIQ was not developed based on models of occupational performance. The CIQ was developed based on the construct of handicap (now participation) in the earlier version of the ICF, the ICIDH. A key difference is that models of occupational performance recognize that each person defines their performance based on individual experiences, values, and goals, thereby emphasizing client-centred notions of meaning, satisfaction, and importance in the measurement of outcomes. In contrast, the ICIDH and the ICF do not attempt to attach notions of meaning, satisfaction, or importance to the concept of handicap or participation. Therefore, although the CIQ is not a complete measure for operationalizing the construct of occupational performance, it was suitable for this study given its parameters. In addition, a recent comparison of three measures of participation (i.e. CIQ, Craig Handicap Assessment and Reporting Technique, and Disability Rating Scale) recommended the CIQ over the other two instruments to assess rehabilitation outcomes in persons with TBI [52].

Analyses

Descriptive statistics were used to examine the distribution of variables and the amount of missing data, and to describe the sample. Data were also analysed for assumptions of normality, linearity, and homoscedasticity, resulting in the transformation of four variables. Rehabilitation LOS, the SF-36

Mental Health subscale, and the Productivity subscale of the CIQ were subjected to rank transformation, and a logarithmic transformation was used on the TMT, Part B.

Simple linear regression was used to explore the relationship between each of the independent variables and the total and subscale scores of the CIQ, and to determine eligible variables for the multiple linear regression analyses. Multiple regression models were constructed by using all covariates that were significant at $p < .20$ on bivariate analyses. An entry criterion of $p < .20$ was selected so that potentially influential variables would not be overlooked in the multiple regression analyses. Multiple regression analyses were carried out using a hierarchical approach with backwards selection and a significance value of $p < .10$. Separate prediction models were developed for the CIQ total score and each of the CIQ subscales. The independent variables were entered in four separate blocks based on the conceptual framework. The sociodemographic variables were entered first, as they have been shown in the literature to be consistently associated with the CIQ. The injury-related variables were entered second because of their a priori relationship with the remaining independent variables. Novack et al. [59] support the logic of entering sociodemographic variables prior to injury-related variables when using multiple regression techniques to predict outcome following TBI. The post-injury personal variables were entered next. Post-injury environmental variables were entered last, because they have been the least explored in TBI long-term outcome studies. At each level of the hierarchical analysis, variables which did not contribute significantly to the model at $p < .10$ were removed, and variables that were retained were entered into the next conceptual block.

Three variables of interest were also forced into the analysis to examine their influence on the final models regardless of their statistical significance. Chronological age and duration of injury were forced into the analysis to address the key aim of this study, which was to examine the effect of ageing on long-term outcomes. Loss of consciousness was also forced into the analysis because it has been shown to be a significant predictor of outcomes in previous studies using shorter follow-up periods, but has not been examined as extensively over very long-term follow-up periods [60]. Statistical Analysis Systems (SAS) Version 8.2 was utilized for all analyses.

Results

Descriptive analysis

The pre-injury sociodemographic and injury-related characteristics of the study sample have been previously reported [36]. In brief, the mean age of participants was 30.1 years ($SD = 13$, range 14–74 years) at injury and 44.6 years ($SD = 13.1$, range 23–90 years) at follow-up. The ratio of males ($n = 214$) to females ($n = 92$) was 2.3:1. Participants had completed an average of 12.4 years ($SD = 2.1$, range 5–20 years) of education, and 88.6% ($n = 271$) were in paid employment or school, or were homemakers at the time of injury. Prior to injury, 22.5% ($n = 69$) of participants reported having behavioural problems such as problems with alcohol or substance abuse.

The mechanism of injury for 71.6% ($n = 219$) of participants was a motor-vehicle collision. The mean ISS for the sample was 26.2 (SD = 9.2, range 4–50), which indicates a severe level of injury. Approximately 26.1% ($n = 67$) of participants had a LOC of less than 24 h, 25.6% ($n = 66$) had a LOC between one day and one week, and 48.3% ($n = 125$) had a LOC greater than one week. The mean rehabilitation LOS was 56.7 days ($SD = 41.7$, range 1–253 days).

Table I provides descriptive data on the post-injury personal, environmental, and occupational performance characteristics of the study sample.

Bivariate analysis

Results of the bivariate analysis are presented in Table II. The table shows the parameter estimates and significance values for the independent variables regressed with each of the four dependent variables, organized according to the categories of the conceptual framework. The strongest and most consistent bivariate relationships with poorer outcomes were with older age, male gender, post-injury physical function and cognitive ability, as well as with adequacy of finances and availability of transportation. To a lesser extent, not being married, lower education, prior behavioural problems, initial injury severity as measured by length of LOC, LOS in rehabilitation, and emotional support were associated with worse outcomes.

Main and interaction effects

The main and interaction effects of chronological age and duration of injury were examined in relation to the total CIQ score and subscale scores in four separate regression analyses. Results of the analysis revealed no statistically significant association between the main and interaction effects of chronological age and duration of injury and any of the CIQ scores. As such, the interaction term was not included in the multiple regression analysis.

Table I. Post-injury personal, environmental, and occupational performance characteristics of the study sample.

	Mean	SD	Range	*N*	%
Post-injury Personal Characteristics					
SF-36 Physical Function subscale	66.2	32.8	4–100	294	
TMT, Part B (seconds)	142.2	85.5	36–300	235	
SF-36 Mental Health subscale	74.1	21.2	0–100	275	
Duration of injury (years)	14.2	4.4	7–24	306	
Post-injury Environmental Characteristics					
Number of rehabilitation services received	1.2	1.2	0–4	306	
Emotional support					
Yes				263	89.5
No				31	10.5
Instrumental support					
Yes				269	94.4
No				16	5.6
Transportation (access/availability)					
Yes				261	85.3
No				45	14.7
Finances (affording things)					
Easily/fairly easily				178	58.2
Less easily/absolutely not				128	41.8
Post-injury Occupational Performance Characteristics					
CIQ: total score	16.5	6.5	0–28	291	
Home integration	4.8	3.1	0–10	296	
Productivity	3.7	2.3	0–7	298	
Social Integration	7.9	3.1	0–12	293	

Table II. Bivariate analysis of independent variables with post-injury occupational performance.

	Total CIQ		Home integration		Productivity		Social integration	
Conceptual categories	*B*	*p*	*B*	*p*	*B*	*p*	*B*	*p*
Pre-injury Sociodemographic Factors								
Chronological age	−.167	< .0001	−.043	.003	−2.24	< .0001	−.064	< .0001
Gender	3.15	.0001	2.15	< .0001	11.82	.262	2.15	< .0001
Marital status	−3.13	< .0001	−.673	.080	−38.79	.001	−1.33	.0005
Education at injury	.519	.004	.145	.095	4.47	.052	.272	.002
Employment at injury	1.00	.478	.156	.813	30.12	.082	.499	.467
Behavioural problems	−2.69	.002	−.406	.350	−33.26	.003	−1.40	.001
Injury-related Factors								
Injury Severity Score	.008	.857	−.019	.372	.336	.538	.018	.388
Loss of consciousness	−.973	.015	−.552	.004	−10.56	.034	−.301	.11
Length of stay (rehabilitation) (ranked)	.002	.683	.002	.334	−.123	.023	.004	.042
Post-injury Personal Factors								
SF-36 Physical Function subscale	.126	< .0001	.028	< .0001	1.68	< .0001	.055	< .0001
TMT, Part B (seconds) (log)	−6.14	< .0001	−1.97	< .0001	−71.27	< .0001	−2.49	< .0001
SF-36 Mental Health subscale (ranked)	.017	< .0001	−.0005	.814	.235	< .0001	.011	< .0001
Duration of injury	−.060	.495	−.006	.889	−1.51	.166	−.014	.74
Post-injury Environmental Factors								
Emotional support	2.97	.018	−383	.525	26.36	.092	2.01	.0007
Instrumental support	1.03	.552	−1.30	.112	32.13	.130	1.91	.02
Spectrum of Rehabilitation services received	−.520	.063	−.005	.972	−13.39	.0001	−.223	.1
Finances	4.04	< .0001	.936	.012	58.15	< .0001	1.75	< .0001
Transportation	8.23	< .0001	2.52	< .0001	85.64	< .0001	3.91	< .0001

Multiple regression analysis

Tables III–VI present the final regression models with the R^2 value and summary statistics for the CIQ total and three subscales. The values for the change in R^2 for each of the four steps of the hierarchical regression analyses are summarized below each table. The change in R^2 shows that the pre-injury socio-demographic factors entered in step 1 and the post-injury personal factors entered in step 3 explained the greatest proportion of variance in CIQ total and subscale scores. Injury-related factors

Table III. Final regression model of independent variables on total CIQ.

	$R^2 = 0.5131$[a]		
Independent variables	Coefficient	SE	p-value
Intercept	17.91	3.94	< .0001
Chronological age[b]	−0.03	0.03	0.39
Gender	3.09	0.70	< .0001
Loss of consciousness[b]	−0.27	0.33	0.43
Duration of injury[b]	0.11	0.08	0.18
SF-36 Physical Function subscale	0.08	0.01	< .0001
TMT, Part B (log)	−2.91	0.65	< .0001
Transportation	3.47	1.11	0.002

[a] $R^2 = .23$ for Step 1; $\Delta R^2 = .25$ for Step 2; $\Delta R^2 = .43$ for Step 3; $\Delta R^2 = .51$ for Step 4 ($p < .10$). [b] Forced into the model.

Table IV. Final regression model of independent variables on the Home Integration subscale of the CIQ.

	$R^2 = 0.2696$[a]		
Independent variables	Coefficient	SE	p-value
Intercept	9.79	2.19	< .0001
Chronological age[b]	−0.02	0.02	0.29
Gender	2.28	0.42	< .0001
Loss of consciousness[b]	−0.36	0.20	0.07
Duration of injury[b]	0.10	0.05	0.04
TMT, Part B (log)	−1.36	0.36	0.0004
Instrumental support	−2.57	0.84	0.002
Transportation	1.29	0.65	0.05

[a] $R^2 = .15$ for Step 1; $\Delta R^2 = .16$ for Step 2; $\Delta R^2 = .25$ for Step 3; $\Delta R^2 = .27$ for Step 4 ($p < .10$). [b] Forced into the model.

Table V. Final regression model of independent variables on the Productivity (ranked) subscale of the CIQ.

	$R^2 = 0.5300$[a]		
Independent variables	Coefficient	SE	p
Intercept	197.15	48.25	< .0001
Chronological age[a]	−0.46	0.39	0.24
Behavioural problems	−30.33	9.35	0.001
Loss of consciousness[a]	2.34	4.33	0.59
Length of stay	−0.13	0.05	0.005
Duration of injury[a]	−1.33	1.02	0.19
SF-36 Physical Function subscale	1.36	0.16	< .0001
TMT, Part B (log)	−20.92	8.38	0.01
Transportation	26.14	13.98	0.06

[a] $R^2 = .17$ for Step 1; $\Delta R^2 = .23$ for Step 2; $\Delta R^2 = .46$ for Step 3; $\Delta R^2 = .53$ for Step 4 ($p < .10$). [b] Forced into the model.

Table VI. Final regression model of independent variables on the Social Integration subscale of the CIQ.

	$R^2 = 0.2980$[a]		
Independent variables	Coefficient	SE	p
Intercept	10.23	1.87	< .0001
Chronological age[b]	−0.008	0.02	0.62
Behavioural problems	−0.89	0.40	0.03
Loss of consciousness[b]	−0.10	0.18	0.59
Length of stay (ranked)	0.004	0.002	0.05
Duration of injury[b]	0.04	0.04	0.37
SF-36 Physical Function subscale	0.02	0.007	0.001
TMT, Part B (log)	−1.07	0.34	0.002
SF-36 Mental Health subscale (ranked)	0.007	0.002	0.002

[a] $R^2 = .15$ for Step 1; $\Delta R^2 = .18$ for Step 2; $\Delta R^2 = .29$ for Step 3; $\Delta R^2 = .30$ for Step 4 ($p < .10$). [b] Forced into the model.

entered in step 3 and post-injury environmental factors entered in step 4 contributed only a small proportion of the total variance relative to the pre-injury sociodemographic and post-injury personal factors. The three variables forced into the analysis contributed to less than 2% of the total variance for each of the four final models.

Table III shows the final model for the total CIQ. Female gender, lower (indicating better) TMT, Part B (log) scores, higher (indicating better) physical function scores, and greater availability/access to transportation accounted for 51% (50% adjusted) of the variance in total CIQ scores.

The final model for the Home Integration subscale is shown in Table IV. Female gender, shorter LOC, longer duration of injury, lower (indicating better) TMT, Part B (log) scores, higher (indicating better) physical function scores, less availability of instrumental support, and greater availability/access to transportation accounted for 27% (24% adjusted) of the variance in home integration scores.

Table V shows the final model for the Productivity (ranked) subscale. Presence of prior behavioural problems, shorter rehabilitation LOS (ranked), lower (indicating better) TMT, Part B (log) scores, higher (indicating better) physical function scores, and greater availability/access to transportation accounted for 53% (51% adjusted) of the variance in productivity scores.

The results of the final model for the Social Integration subscale are presented in Table VI. Prior behavioural problems, longer rehabilitation LOS (ranked), lower (indicating better) TMT, Part B (log) scores, higher (indicating better) physical function scores, and higher (indicating better) Mental Health scores (ranked) accounted for 30% (27% adjusted) of the variance in social integration scores.

Discussion

This study examined the association of specific pre-injury sociodemographic, injury-related, post-injury personal and post-injury environmental factors with occupational performance outcomes for adults any years after moderate to severe TBI. A key finding in this study was the substantial amount of variance explained in occupational performance outcomes. Another interesting finding was the independent lack of association between the age-related variables and occupational performance outcomes. In addition, this study is one of the few to utilize a conceptual framework to drive the research and is one of the few cohort studies with a mean follow-up of 14 years post-injury.

The amount of variance (51%) in total CIQ scores explained in this study was higher than that reported in previous studies by Doninger et al. [23] and Fleming et al. [25], who reported 14% and 23% of explained variance in total CIQ scores, respectively. The amount of explained variance for the CIQ subscale scores in this study was also higher, particularly for the Productivity subscale, compared to previous studies [24,25]. Researchers using measures conceptually similar to the CIQ have managed to explain between 14% and 28% of variance in outcomes [5,6,22]. The inclusion of additional personal (i.e. physical, cognitive, and affective) and environmental (i.e. social, institutional, and physical) variables, guided by the conceptual framework, is likely to have contributed to the higher amount of explained variance. Previous studies [23] have included only one aspect of function at the level of the person (e.g. cognitive) or one aspect of the environment (e.g. physical).

Results from the regression analyses did not fully support the two study hypotheses. First, the hypothesis that the interaction of chronological age and duration of injury would limit domains of occupational performance to a greater degree than either factor would independently was not supported. Previous TBI outcome studies do not appear to have examined the interaction effect of age and duration of injury on long-term outcomes; however, several studies in the area of ageing with a spinal cord injury have found significant results [61–65]. The reason for a lack of significant interaction effects in this study may stem from the relatively young sample, which had a mean age of 44.6 years (range 23–90) at time of follow-up. If, as hypothesized, decline of function in ageing with a TBI is a combination of age and duration of injury, then many individuals in the sample may not yet be demonstrating significant ageing changes because of their relatively young age combined with a mean of 14 years duration of injury.

The hypothesis that older chronological age and a longer duration of injury would be independently associated with worse occupational performance outcomes was also not supported. However, it should be noted that age was one of the strongest predictors in the bivariate analyses. With regard to age, the ability to make comparisons to other studies is limited because, to date, TBI long-term outcome research has primarily examined the predictive ability of age at injury instead of chronological age. One of the only previous studies [5] that examined the effect of chronological age found that older age was associated with worse outcomes in the domains of productivity and leisure at mean time of 13 years post-TBI; however, the study did not include any cognitive or injury-severity variables in the analysis, which may have mediated the effect of chronological age.

One potential explanation for the lack of direct independent association between chronological age and occupational performance outcomes in this study is that the relationship could be mediated by other variables. For example, when chronological age was entered in the first and second step of the hierarchical multiple regression analysis, it was found to be a significant predictor of occupational performance outcomes when examined in relation to other sociodemographic and injury-related variables. However, when chronological age was entered in the third step, with the block of post-injury personal variables (i.e. SF-36 and TMT, Part B), it was no longer a significant predictor. In fact, Spearman correlation coefficients indicated significant relationships between advancing age and poorer physical and cognitive abilities.

When forced into the analysis, a longer duration of injury was found to be associated with better outcomes in the domain of self-care. This study had hypothesized that living with a TBI for an extended duration places increased stress and demands on the person, which may, in turn, lead to worse occupational performance outcomes. However, the mean duration of injury in this study was only 14 years. Perhaps future studies with follow-up periods of two or three decades post-injury may find significant associations between a longer duration of injury and worse occupational performance outcomes. An alternative hypothesis that also requires further investigation is that a longer duration of injury may lead to better outcomes as individuals with TBI continue to adapt and recover over time.

Predictors of post-injury occupational performance

Two of the six pre-injury sociodemographic variables (gender and behavioural problems) were significant predictors of occupational performance outcomes. The finding that male gender predicted worse outcomes in the domain of self-care is in agreement with previous studies [23,24]. This finding is most likely driven by items on the home integration scale of the CIQ, which focus on the traditional roles women play in performing home activities. The finding that the presence of pre-injury behavioural problems predicts worse occupational performance outcomes coincides with previous studies [29,32]. This finding suggests that rehabilitation professionals need to pay attention to the importance of pre-injury behavioural problems, such as a history of substance abuse, and its influence on very long-term outcomes, particularly in the domains of productivity and leisure. Clinically, rehabilitation professionals can play a key role in screening for the influence of pre-injury behavioural problems on occupational performance outcomes and in making appropriate referrals for individuals with such problems.

Two of the injury-related variables—LOC and rehabilitation LOS—helped explain the variance in occupational performance outcomes, although it is important to note that these variables accounted for less of the explained variance than the pre-injury sociodemographic or post-injury personal variables. The finding that longer durations of LOC and LOS predict worse occupational performance outcomes coincides with previous studies [24–26,28]. Although this study found that a longer LOS was associated with worse productivity outcomes, interestingly, it also found that a longer LOS was associated with better outcomes in the domain of social and leisure activities. This finding is difficult to interpret, given that a longer LOS typically indicates greater injury severity. It could be that participants with a longer LOS are less integrated into self-care or productivity domains because of the potentially greater cognitive demands in these domains, and therefore spend a greater amount of time in social and leisure activities.

All four of the post-injury personal variables contributed to explaining the variance in occupational performance outcomes. This study found that lower levels of physical and cognitive function predict worse outcomes, primarily in the domains of productivity and leisure, which is in agreement with previous studies [5,19,23,29]. In this study, lower levels of affective status were associated with worse outcomes in the domain of leisure, but not in the domains of self-care and productivity. This finding may be attributed to the greater affective and social interaction demands of leisure activities than self-care or productive activities.

Two of the five post-injury environmental variables—access to and availability of transportation and availability of instrumental support—helped explain the variance in occupational performance outcomes. Less access to and availability of transportation predicted worse outcomes in the domains of self-care and productivity. Interestingly, transportation was not a significant predictor of leisure outcomes where one might think its availability would play a significant role in enabling individuals to access social and leisure activities in the community. Perhaps the majority of individuals with TBI in this study were engaged in social and leisure activities at home (e.g. talking on the phone) instead of in the broader community. The finding that a greater availability of instrumental support predicted worse outcomes could be explained by the scoring system for the CIQ. Greater points are awarded for performing home activities alone than for performing them with others. As such, individuals reporting a greater availability of instrumental support in this study would mostly likely perform home activities with assistance, thus scoring lower on this subscale.

Although the investigated post-injury environmental factors were found to contribute less of the variance in occupational performance outcomes than post-injury personal factors, this does not mean that rehabilitation professionals should ignore interventions focused on the environment when working with adults many years post-TBI. Indeed, for persons living long-term with disabilities, frequently the only element of the person, environment, or occupation (i.e. task or activity) that can be adapted easily is the environment [66]. Looking beyond deficits at the level of the person is important so that clients and rehabilitation professionals can pay attention to aspects of the environment [67], which tend to receive less focus than interventions aimed at addressing deficits in the area of cognitive-behavioural function or in the domains of self-care and productivity.

Conceptual and methodological issues

A key conceptual issue in this study was the attempt to link the construct of occupational performance to the CIQ. Although the CIQ does capture the broad domains of occupational performance (i.e. self care, productivity, leisure), it does not take into account client-centred notions of whether individuals choose to participate in a specific role or activity and whether or not they are satisfied with their performance.

Limitations associated with the primary outcome measure used in this study, the CIQ, have been previously addressed [23,49,68]. Additional measurement limitations include the lack of standardized environmental measures, the potential for pre-injury behavioural problems that may have been missed due to the reliance on retrospective chart data and self-report, and the lack of more rigorous measures of injury-severity. In particular, the use of primarily dichotomous environmental variables and the distribution of environmental variables may have limited the strength of their contribution to the regression analysis. Future research needs to include measures that allow for the analysis of the influence of broad environmental factors (e.g. physical, social, economic, attitudinal, and political). For instance, measures such as the Measuring the Quality of the Environment [69] assess the enabling and constraining aspects of the environment on an individual's roles and participation in the community. Second, because the postinjury outcomes were measured at one point in time in this study, it was not possible to capture changes in occupational performance as a result of chronological ageing. Additional studies with longitudinal designs, multiple follow-up periods, and control groups are needed to capture changes in outcomes as a result of the ageing process and to explore whether TBI accelerates aspects of the ageing process. Funding of such studies over a lengthy follow-up period, however, is a challenge.

This study has numerous strengths and contributes to TBI long-term outcome research in several ways. First, this study introduces a conceptual model, which is generalizable to a broad range of disciplines. Second, this study had a large sample size, one of the longer lengths of follow-up, and used face-to-face interviews to gather post-injury data. Third, standardized measures of cognitive, physical, affective, and occupational performance outcomes were utilized. Finally, this was one of the few studies to explore the effect of important environmental variables on long-term outcomes and to specifically explore the effects of chronological age and duration of injury. The finding that pre-injury behavioural problems; post-injury physical, cognitive, and affective deficits; and access to and availability of transportation contribute significantly to the prediction of occupational performance outcomes at a mean time of 14 years post-TBI provides support for ongoing, rehabilitation efforts targeted at these areas. In addition, findings from this study suggest that the extent of health care benefits and long-term rehabilitation services should not be determined solely on factors such as injury severity, chronological age, and length of time post-injury.

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