Predictors of health-related quality-of-life following traumatic brain injury

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Abstract

Primary objective: To examine the predictive associations of family satisfaction, functional impairment, pain, and depression on health-related quality-of-life (HRQoL) among persons with traumatic brain injury (TBI) through structural equation modelling (SEM).

Research design: Participants were part of a larger longitudinal study of adjustment following TBI. Direct and indirect effects of predictor variables on HRQoL were analyzed through SEM.

Methods and procedures: The sample included 131 participants with TBI (89 men, 42 women) who had been discharged from an acute care hospital. The Sickness Impact Profile was administered to measure HRQoL at or beyond 24 months post-discharge. Predictor variable measures included the Functional Independence Measure, Family Satisfaction Scale and single items assessing the presence of pain and depression.

Main outcomes and results: SEM revealed direct effects of functional impairment (p < 0.001), family satisfaction (p < 0.01), depression (p < 0.05) and pain (p < 0.01) on HRQoL. Indirect effects from functional impairment (p < 0.05) and pain (p < 0.05) to HRQoL through depression were also present.

Conclusions: The presence of pain and depression, greater functional impairment and lower family satisfaction were predictively associated with lower HRQoL. Depression further mediated the effects of pain and functional impairment on HRQoL. The present study advances understanding of the ways in which pain, depression and functional impairment predict HRQoL.

Introduction

Health-related quality-of-life (HRQoL) is an important outcome following traumatic brain injury (TBI) valued by clinicians, individuals who live with TBI and their families. HRQoL has many components that can be operationalized and measured in various ways [1, 2]. Predicting HRQoL over time is a rather tricky enterprise, however, as some clinically intuitive factors are inconsistently associated with HRQoL (e.g. injury severity, functional impairments), others seem to account for relatively small amounts of variance in HRQoL (e.g. marital status) [1–3] and some issues, such as persistent pain, depression and other secondary complications, merit further empirical scrutiny [4–6].

Recent conceptualizations of adjustment following acquired disability posit that disability, personal and familial factors should be studied with statistical models to examine the co-occurring relations that exist among predictor variables and the context in which these variables relate to HRQoL over time [7, 8]. Furthermore, positive adjustment following TBI may be well served by theoretical perspectives that appreciate the relative contributions of several factors often present in studies of HRQoL following disability [9]. For example, functional abilities may be construed as a capacity to engage in ‘intentional activities’—behavioural, volitional or cognitive—that account for a greater degree of variance in happiness and well-being than ‘circumstantial’ variables (e.g. marital status) [10].

The capacity to engage in intentional activities may be facilitated or offset by the psychological resources and dynamics present in the family life of persons with TBI [11, 12]. Families that exhibit flexibility in adapting to changes in roles and relationships in times of stress have a positive effect on adjustment post-TBI [13]. Prospective research has also revealed significant and profound effects of family cohesion and satisfaction on life satisfaction over the first 5 years following medical discharge for TBI [14].

To understand HRQoL following disability, it is essential to understand the mechanisms of behavioural and psychosocial variables implicated in the prediction of secondary complications and their deleterious effects on HRQoL [15]. The present study was conducted to examine a predictive...
structural equation model of HRQoL among persons with TBI, taking into consideration the degree to which functional impairment, family satisfaction, depression and pain directly predict HRQoL. In addition, it examined the mediating effects of depression in the prediction of HRQoL. In this fashion, then, this study sought to gain important information about the predictive association of these variables with HRQoL among persons with TBI.

**Method**

**Procedure**

Participants were part of a larger longitudinal study of adjustment following disability by the Injury Control Research Center (ICRC) at the University of Alabama at Birmingham. Participants included persons who had incurred one or more of four disabling injuries (TBI, severe burns, spinal cord injury or intra-articular fractures of the lower extremities) and who had been discharged from a sub-set of nine hospitals surrounding north-central Alabama. Participants were identified from medical records at acute care (e.g. immediate short-term treatment for TBI) hospitals and contacted at 12 months post-discharge to participate in the study. Individuals were invited to participate if they (1) were residents of and injured in Alabama; (2) were at least 18 years old when injured; (3) were inpatients at an acute care hospital for 3 or more days; (4) were discharged alive from an acute care hospital between 1 October 1989 to 30 September 1992; and (5) consented to participate in regular follow-up interviews by telephone conducted by ICRC personnel.

Eligible persons were contacted by mail at 12 months post-discharge to participate in the study. Pre-addressed postcards containing consent forms were included. If the consent form was not returned by mail, ICRC personnel contacted eligible persons by phone to explain the study in greater detail. Persons contacted by ICRC personnel provided informed consent over the telephone. Data was collected from all consenting persons by a trained interviewer. Interviews were conducted with participants’ spouses, caregivers and close relatives when participants were unavailable or unable to answer questions over the telephone. Additional demographic and clinical information was collected from acute care hospital records.

As part of the larger ICRC project, measures were administered to participants through telephone interviews and mailed self-report questionnaires at 12, 24, 48 and 60 months post-discharge from an acute care hospital. Data were collected on demographic and social characteristics, rehabilitation services and outcomes, other medical services, overall health status, psychological and physical adjustment to TBI and secondary complications following TBI. For the present study only a sub-set of measures were analysed including the Functional Independence Measure (FIM) [16] and the Family Satisfaction Scale (FSS) [17] administered at the 12th month post-discharge from acute care hospitalization and single pain and depression items administered at the 24th month post-discharge.

The Sickness Impact Profile (SIP) [18] was added to the ICRC protocol in 1994 and the measure was mailed to active participants in the ICRC project. Consequently, participants who received the SIP were at or beyond the 24th month of their participation. Due to administrative error, the exact dates on which the SIP was returned were not recorded.

**Participants**

Of the 1026 eligible persons with TBI contacted to participate in the overall ICRC project, 609 individuals provided informed consent. A sample of 131 participants from the 609 consenting persons completed the SIP. This sub-set included 89 men (average age = 35.26, SD = 15.40) and 42 women (age = 43.31, SD = 19.06). The majority identified their ethnicity as Caucasian (n = 102); 28 identified as African American, and one identified as Hawaiian Islander. Independent t-tests and chi-square tests were conducted to examine demographic differences between participants with TBI in the ICRC project who did and did not complete the SIP. No statistically significant demographic differences including age (p = 0.58), gender (p = 0.77), ethnicity (p = 0.06) and injury severity (p = 0.22) were found between the two groups of ICRC participants with TBI.

The Abbreviated Injury Scale (AIS) [19, 20] was used to classify the severity of TBI. The AIS provides an anatomical description of injury severity for six body regions, including the head (HAIS), based on ordinal values ranging from minor injury (1) to maximum injury or virtually unsurvivable (6) [19, 21]. Overall AIS ratings and head AIS ratings were computed through the use of a computerized table, the ICDMAP by converting ICD-9-CM discharge diagnosis codes to AIS scores [20]. Forty-two per cent of the present sample had overall AIS ratings of moderate injury severity (HAIS = 50.4%), 32.8% of serious injury severity (HAIS = 24.8%) and 24.4% (HAIS = 24.8%) of severe or critical injury severity, respectively. Further, the majority of participants (76.6%) did not receive inpatient rehabilitation services. The number of days of inpatient rehabilitation among participants who received services ranged from 0–90 days (23.4%; average number of days = 7.73, SD = 17.55 days).

**Measures**

**Functional independence measure**

The telephone version of the Functional Independence Measure (FIM) [16] was administered at the 12th month of participating in the study. The FIM is a self-report questionnaire that assesses the level of assistance needed to complete activities of daily living across six functional domains including self-care, locomotion, sphincter control, social cognition, transfers and communication. The FIM consists of 18 items with Likert-type rating scales ranging from need for total assistance (1) to complete independence (7). Higher scores on the FIM indicate greater functional independence. Previous research has documented the reliability and validity of the FIM in TBI rehabilitation [22]. In the present study, the internal consistency of the FIM was 0.97, FIM items were linearized utilizing Rasch scaling procedures in order to increase item variability, ensure item quality, stability and reliability [14]. For a more thorough discussion of the Rasch analyses of FIM scores from the ICRC dataset, see Resch et al. [23].
Family satisfaction scale

The Family Satisfaction Scale consists of 14 items developed to measure family adaptability and cohesion (FSS) [17]. It was administered at the 12th month of the study. Responses are recorded on a Likert-type scale ranging from dissatisfied (1) to extremely satisfied (5). Higher scores indicate greater family satisfaction. For the ICRC project, two items (e.g. Item 4 and Item 5) on the FSS were modified to eliminate the focus on satisfaction of dependent children with parental actions that was present among the two items on the original FSS. Previous research with persons with TBI from the ICRC project reported internal consistency of the revised FSS items to be 0.94 at 12 months post-discharge and 0.95 at 60 months post-discharge from acute care hospitalization [24]. Consistent with Underhill et al. [24], the internal consistency of the revised FSS items in the present study was 0.94.

Pain item

A single item was used to assess the presence of pain secondary to TBI: ‘Have you ever been told by a doctor that you have pain as a result of your injury?’ Responses were coded as ‘yes’ or ‘no’. This item was included in the current study to indicate the presence of pain secondary to TBI. It was administered at the 24th month of the study. Of the 131 participants, 50 (38%) endorsed being told by their doctor that they have pain as a result of their injury.

Depression item

A single item was used to measure the presence of depression secondary to TBI: ‘Have you ever been told by a doctor that you have depression as a result of your injury?’ Responses were coded as ‘yes’ or ‘no’. This item was included in the current study to indicate the presence of depression secondary to TBI. It was administered at the 24th month of the study. Of the 131 participants, 37 (28%) endorsed being told by their doctor that they have depression as a result of their injury.

Sickness impact profile

The Sickness Impact Profile, a comprehensive measure of physical and psychosocial aspects of health-related quality-of-life (SIP) [18], was used as an omnibus measure of HRQoL. The SIP includes 136 items assessing the presence or absence of injury or health-related functional difficulties. Items are divided into 12 sub-scales including body care and movement, social interaction, emotional behaviour, ambulation, recreation and past times, eating, alertness behaviour, home management, communication, sleep and rest, work and mobility. The 12 sub-scales are combined to produce a total SIP scale score. Additionally, seven sub-scales are divided into two dimensional scales: (1) Physical Impairment, a physical dimension scale comprised of the mobility, body care and movement and ambulation sub-scales; and (2) Psychosocial Impairment, a psychosocial dimension comprised of the communication, alertness behaviour, emotional behaviour and social interaction sub-scales. SIP total and dimensional scale scores range from 0–100. Higher scores indicate greater impairment in physical and psychosocial aspects of health-related quality-of-life. Previous research has documented the reliability and validity of the SIP in TBI rehabilitation [25–27]. In the present study, the internal consistency coefficient of the total SIP scale was 0.97.

Data analysis

Descriptive statistics were generated using SPSS version 20.0. Relationships among demographic characteristics and self-report variables were examined by calculating Pearson r correlation coefficients, phi coefficients and point-biserial correlation coefficients, t-tests and chi-square tests. Univariate and multivariate normality are assumed in structural equation modelling (SEM) due to the inaccurate results produced by non-normal data [28]. As a result, univariate and multivariate normality were assessed by screening the data for outliers, skewness and kurtosis prior to SEM analyses. Data screening was also conducted to identify participants with missing values on model variables. Five participants were identified and the listwise deletion method was employed to exclude these participants from the SEM analyses.

A path model was created to examine the direct effects of functional impairment (e.g. FIM) and family satisfaction (e.g. FSS) at 12 months post-discharge, as well as pain and depression at 24 months post-discharge on HRQoL (e.g. SIP) at or beyond 24 months post-discharge among persons with TBI. Structural equation modelling was chosen for the present analysis due to SEM’s exploratory and confirmatory methodology for furthering theory development. The a priori theoretically-derived model presented in Figure 1 was analysed by treating all variables as observed (e.g. measured) variables. Statistically significant paths were expected to flow from each exogenous predictor variable (functional impairment, pain, family satisfaction) to the endogenous outcome variables including depression at 24 months post-discharge and HRQoL at or beyond 24 months post-discharge. Additionally, depression was theoretically assumed to mediate the relationship between functional impairment, pain and family satisfaction, with statistically significant paths flowing indirectly from each of the exogenous predictor variables (functional impairment, pain and family satisfaction) to the endogenous outcome variable (HRQoL) through depression as the endogenous mediating variable.

Mplus version 6.11 was used for all SEM analyses due to the ability of the program to include both categorical and continuous endogenous variables within the same path model [29]. A bivariate correlation matrix was constructed prior to conducting SEM analyses in order to assess statistically significant correlations between the model variables. Subsequent path model analyses were conducted using the weighted least squares with means and variances (WLSMV) estimator and the probit link function due to the presence of an endogenous categorical variable (i.e. depression) within the model [29]. Recommended fit statistics including the chi-square test of model fit, root-mean square error of approximation (RMSEA) and weighted root mean square residual (WRMR) were used to assess model fit [30, 31]. Adequate model fit is typically achieved when chi-square tests of model fit are statistically non-significant, RMSEA scores are approximately less than 0.06 and WRMR scores are...
approximately less than 1.0 [31, 32]. As a result, criteria for adequate model fit were employed in the present study.

To examine indirect effects (e.g. mediation) between variables, bootstrap confidence intervals were computed using the Mplus program as discussed by Preacher and Hayes [33]. The bootstrap analysis is a non-parametric re-sampling technique that does not invoke the assumption of normality of the sampling distribution [33]. Additionally, this analysis provides increased statistical power with small sample sizes and endogenous categorical variables compared to other statistical analyses for indirect effects [34, 35]. Bootstrapping provides empirical approximations of sampling distributions and confidence intervals through a computationally intensive re-sampling procedure. The constructed confidence intervals are used to estimate indirect effects of mediating variables within SEM [33]. The bootstrap analysis may be considered the closest approximation to external replicability without collecting new data [36].

Results

Demographical information

Results of t-tests and chi-square tests revealed a statistically significant difference between participants who did and did not receive inpatient rehabilitation services with regards to the total FIM score (p < 0.001). On average, participants who did not receive inpatient rehabilitation services had greater functional independence compared to those who received inpatient rehabilitation services. There were no additional statistically significant differences between demographic variables and model variables.

Preliminary analyses

Univariate and multivariate normality was assessed prior to SEM analyses. Univariate outliers were identified through inspection of z-score frequency distributions (e.g. |z| > 3 represents univariate outlier) [28]. Upon inspection, one univariate outlier was detected in the data. As suggested by Kline [28], the univariate outlier score was converted to a value equal to the most extreme score within 3 SD of the mean. Mahalanobis distance criterion (p < 0.001) was employed to identify multivariate outliers [28]. No multivariate outliers were identified in the data. Skewness and kurtosis were also assessed to determine normality. Skewness and kurtosis values for all model variables were within acceptable limits to proceed with the SEM analyses. Further, the listwise deletion method excluded five participants from the final SEM analysis due to missing data. As a result, SEM analyses were conducted with 126 participants.

All exogenous variables were allowed to freely correlate in the SEM analyses. Examination of the bivariate correlation matrix suggested that there were two statistically significant correlations between the exogenous predictor variables functional impairment and family satisfaction (0.20, p < 0.05), as well as family satisfaction and pain (−0.24, p < 0.01). Thus, the statistically significant covariance paths between the exogenous predictor variables are displayed in Figure 1 and Figure 2. Bivariate correlations, means and standard deviations for all model variables used in subsequent analyses are presented in Table I.

![Figure 1. A priori path model of functional impairment, pain, family satisfaction, depression and health-related quality-of-life.](image)

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FIM</td>
<td>−</td>
<td>0.20*</td>
<td>−0.11</td>
<td>−0.24**</td>
<td>−0.47**</td>
<td>2.79</td>
<td>2.04</td>
</tr>
<tr>
<td>2. FSS</td>
<td>−</td>
<td>−</td>
<td>−0.25**</td>
<td>−0.15</td>
<td>−0.36**</td>
<td>54.69</td>
<td>12.68</td>
</tr>
<tr>
<td>3. PAIN</td>
<td>−</td>
<td>0.29**</td>
<td>−</td>
<td>−0.36**</td>
<td>1.39</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>4. DEP</td>
<td>−</td>
<td>0.35**</td>
<td>−</td>
<td>−</td>
<td>1.29</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>5. HRQoL</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>13.77</td>
<td>14.39</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01.

FIM, Functional Independence Measure-Rasched (observed range 3.50–5.28); FSS, Family Satisfaction Scale (observed range 14–70); PAIN, Pain Item (observed range 0.0–1.0); DEP, Depression Item (observed range 0.0–1.0); HRQoL, Sickness Impact Profile (observed range 0.0–55.91).
**Model evaluation**

The theoretically-derived *a priori* path model was evaluated for model fit. Fit statistics for the *a priori* path model indicated poor fit for the data $\chi^2 (1) = 0.0$, $p < 0.001$ (RMSEA = 0.0, WRMR = 0.0). As a result, SEM analyses were conducted to examine the statistical significance of the paths within the *a priori* model. Consequently, the paths within the original model were re-fitted to test an empirically-derived model.

The corrected model excluded the path between family satisfaction and depression, because the path coefficient was not statistically significant (unstandardized coefficient = −0.005, standardized coefficient = −0.060, $p > 0.05$). The corrected model—displayed in Figure 2—was constructed with three exogenous variables (functional impairment, pain, family satisfaction) and two endogenous variables (depression and HRQoL). This empirically-derived model evidenced adequate model fit to the data $\chi^2 (1) = 0.281$, $p = 0.596$ (RMSEA = 0.0, WRMR = 0.0). Thus, the model fit statistics provided evidence that the path coefficients for the corrected model were interpretable.

**Direct effects**

The direct effects for the corrected model are presented in Table II. Greater functional impairment at 12 months post-discharge was predictively associated with the presence of depression at 24 months post-discharge ($p < 0.05$). Additionally, the presence of pain at 24 months post-discharge was predictively associated with the presence of depression at 24 months post-discharge ($p < 0.01$). Greater functional impairment ($p < 0.001$) and lower family satisfaction ($p < 0.01$) at 12 months post-discharge were predictively associated with lower HRQoL at or beyond 24 months post-discharge. The presence of both pain ($p < 0.01$) and depression ($p < 0.05$) at 24 months post-discharge were also predictively associated with lower HRQoL at or beyond 24 months post-discharge. Further, the effects of the corrected model accounted for 19% of the variance in depression at 24 months post-discharge ($R^2 = 0.193$) and 39% of the variance in HRQoL at or beyond 24 months post-discharge ($R^2 = 0.394$).

**Indirect effects**

All possible indirect effects on HRQoL at or beyond 24 months post-discharge were tested with the bootstrap procedure using the Mplus program. The bootstrap procedure constructed 95% confidence intervals of indirect effects to test for statistical significance. The indirect effect of depression at 24 months post-discharge on HRQoL at or beyond 24 months post-discharge was statistically significant ($p < 0.05$). Thus, greater functional impairment at 12 months post-discharge was predictively associated with lower HRQoL at or beyond 24 months post-discharge via functional impairment’s prior predictive association with the presence of depression at 24 months post-discharge. The indirect effect of depression at 24 months post-discharge on the predictive association of pain at 24 months post-discharge and HRQoL at or beyond 24 months post-discharge was also statistically significant ($p < 0.05$). Consequently, the presence of pain at 24 months post-discharge...
post-discharge was predictively associated with lower HRQoL at or beyond 24 months post-discharge via pain’s prior predictive association with the presence of depression at 24 months post-discharge. The indirect effects for the corrected model are presented in Table III.

### Discussion

The presence of pain and depression 24 months following discharge from acute care hospitalization were predictively associated with lower HRQoL assessed at or beyond 24 months post-discharge. Pain is often a secondary complication following traumatic onset of TBI [6], yet its deleterious effects on quality-of-life in TBI have been under-studied. Therefore, the inverse relationships of the presence of pain and depression with HRQoL merit further investigation.

The present study provides additional insight into the predictive relationships of pain and functional impairment with HRQoL through indirect effects of depression. In terms of pain, the mediating effects of depression suggest that pain may engender depressive symptoms such as negative moods and unpleasant experiences that predict further decreases in HRQoL among persons with TBI. Relatively high rates of pain have been found among persons with TBI who are depressed [4]. Subsequently, the mediating effect of depression on the predictive relationship of functional impairment and HRQoL suggests that impairments in functional abilities following TBI may increase the probability of depressive symptoms which, in turn, compromises HRQoL.

The relationships between pain, functional impairment, depression and HRQoL in the present study are consistent with a similar pattern observed in a prospective study of depression, pain and functional impairment following TBI [37]. Similar to our results, pain was prospectively predictive of depression assessed 1 year later and depression mediated the relationship of pain to community participation. The measure of HRQoL in the present study (the SIP) has specific scales that assess social integration, recreational pursuits and desired activities and duties in the home [18]. Thus, it appears that disruption in meaningful activities and resulting decreases in HRQoL following TBI are prospectively influenced by psychological distress [4]. However, unlike the Hoffman et al. [37] study, the presence of pain maintained a direct relationship to HRQoL in the present study in addition to the indirect effect of pain to HRQoL through depression. The use of different measures for pain and depression in this study and the Hoffman et al. [37] study may account for these different results, although the use of a context analytic model may have been more sensitive to co-occurring relationships in this sample compared to the regression models used by Hoffman et al. [37]. Collectively, these studies indicate that the presence of pain and depression, whether assessed with brief or standardized measures, are important factors in HRQoL that merit clinical and empirical attention. Future research examining the predictive pathways between pain, functional impairment and depression should be conducted to fully understand the inter-relationships between predictors of HRQoL among persons with TBI.

The measure of family satisfaction in the current study is arguably indicative of a flexible, resilient and cohesive family environment [38]. The results of the present study provide additional evidence that a resilient, flexible family environment is prospectively predictive of well-being (e.g. HRQoL) in the first few years following TBI [14]. Further, these qualities appear to exist independent of marital status [14] and the beneficial effects seem to exert a positive influence on HRQoL independent of functional impairment, pain and depression.

There are several limitations of the present study that should be considered. Self-report measures were used to assess all variables included in the analyses. Simple indicators of pain and depression were used and these were limited to participant self-report of a physician’s diagnosis of pain or depression. Consequently, it is not known what kind of pain the participants may have had (e.g. headache, neuropathic). Interestingly, 28% of the sample reported that a physician had diagnosed depression attributable to TBI and this rate is similar to the rate of depression found in a sample of persons with TBI assessed with an established measure (27%) [39]. Finally, the lack of accurate information about dates on which the SIP was completed and returned to the research team limits one’s ability to examine the full prospective relations of the independent variables to HRQoL over time.

With regards to limitations of the statistical analyses employed in the present study, a power analysis was not conducted because at the time the project began the research team expected a sizeable number of participants. Unfortunately, the SIP was administered to only 131 participants with TBI and the present study was only concerned with this instrument as a measure of HRQoL. Although it is often recommended that SEM analyses should be conducted with sample sizes that exceed 200 participants, several studies have provided evidence that smaller sample sizes can be employed with parsimonious models [40]. The model analysed in this study is relatively parsimonious and, as a result, the sample size appears to be sufficient for the modelling procedures [40]. Further, the results of the present study appear to be stable estimates as evidenced by the presence of adequate model fit and statistically significant direct and indirect effects.

Despite these concerns, the present study indicates that contextual analytic models conducted with SEM are useful for providing important information about the existing and co-occurring relationships between predictor variables and their
combined effects on overall well-being following TBI. Moreover, the present study indicates that quality-of-life following TBI is compromised by factors such as pain, depression and functional impairment that limit or thwart expected and desired activities (as measured by the SIP). In contrast, a supportive family environment, greater functional ability and an absence of pain and depression facilitate HRQoL in a fashion consistent with existing models of well-being and positive adjustment [9, 15]. Further investigations that clarify the prospective role of pain on adjustment following TBI are needed.

Declaration of interest
The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References


