OUTCOME AFTER PARTICIPATION IN A RESIDENTIAL POST-ACUTE BRAIN INJURY REHABILITATION PROGRAM: A COMPARISON BETWEEN TRAUMATIC BRAIN INJURY AND STROKE

A Dissertation

Presented to

The Faculty of the Department

of Psychology

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Doctor of Philosophy

By

Keira M. O'Dell

May, 2013

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INJURY REHABILITATION PROGRAM:

A COMPARISON BETWEEN TRAUMATIC BRAIN INJURY AND STROKE

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ABSTRACT

Objective: The current study was the first, to our knowledge, to compare outcomes of patients with traumatic brain injury (TBI) and stroke who participated in a residential post-acute brain injury rehabilitation (PABIR) program. The aims of this study were to (1) describe the characteristics of TBI and stroke patients presenting to the PABIR level of care, (2) compare the effectiveness of PABIR for patients with TBI versus stroke, and (3) examine those factors which predicted successful outcome from PABIR in these patients.

Participants and Methods: Participants were 72 patients with TBI and 42 patients with stroke who participated in a residential PABIR program. Disability Rating Scale (DRS) and Supervision Rating Scale (SRS) scores were collected upon admission, discharge, and six-month follow-up. The Craig Handicap Assessment and Reporting Technique – Short Form (CHART-SF) was collected at six-month follow-up.

Results: Results from two split-plot, repeated measure ANCOVAs revealed that both TBI and stroke patients demonstrated improvements in DRS and SRS scores from admission to discharge, and gains were well-maintained at six-month follow-up. Regression results revealed that, after controlling for covariates, stroke etiology was related to poorer DRS, SRS, and CHART-SF Mobility outcomes at six-month follow-up, but these relationships dissipated once covariates and age were included in the models. Only CHART-SF Physical Independence was uniquely related to etiology above and beyond covariates and age.

Conclusions: Both TBI and stroke patients experienced improvements in disability and independence level over the course of PABIR. While stroke patients may be vulnerable to poorer outcomes in several domains, these differences are largely related to the disparity in age between the two groups.

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Outcome after Participation in a Residential Post-Acute Brain Injury Rehabilitation Program:

A Comparison between Traumatic Brain Injury and Stroke

Acquired brain injury (ABI) is defined as an insult to the brain that is sustained at some point after birth. ABI can result in significant impairments in cognitive, behavioral, physical, and/or psychosocial functioning, and, thus, is considered a leading cause of disability in North America (Greenwald, Burnett, & Miller, 2003). The two most common etiologies of ABI are traumatic brain injury (TBI) and cerebral vascular accident (CVA), the latter being often referred to as "stroke." Recent data on the incidence of the leading causes of ABI revealed that at least 1.7 million individuals suffer a TBI (Faul, Xu, Wald, & Coronado, 2010) and 795,000 individuals experience a CVA (Center for Disease Control and Prevention [CDC], 2008) annually in the United States. Less common etiologies of ABI include intracranial neoplasms, anoxic/hypoxic events, or infections.

With the advancement of emergency medicine and acute medical care, mortality rates of ABI have decreased relative to twenty or thirty years ago (Hsiang & Marshall, 1998; Kelly, Doberstein, & Becker, 1996). In particular, individuals are now surviving more severe injuries that previously would have resulted in death. Furthermore, inpatient hospital-based rehabilitation lengths of stay for individuals with ABI are continuing to decrease (Ottenbacher, Smith, Illig, Fiedler, & Granger, 2000). As a result, a greater number of ABI patients with significant cognitive, physical, behavioral, social, and/or emotional impairments are in need of further rehabilitation services following their acute hospital stay. These changes are evidenced by the proliferation of non-hospital based programs of cognitive, behavioral, social, educational, and vocational treatments developed across the United States over the past few decades (Cope, Cole, Hall, & Barkan, 1991a). Accompanying the propagation of these "post-acute" rehabilitation programs is a critical need to evaluate their clinical and cost effectiveness through scientifically sound research.

Research efforts aimed at assessing and predicting the effectiveness of post-acute interventions for ABI are valuable to a number of parties. First and foremost, it is imperative to establish the extent to which these programs can decrease disability and improve quality of lives for those individuals who have suffered ABIs. Secondly, this area of research has clear implications for the family members and caregivers of those with ABI. A third interested party includes those invested in the cost effectiveness of post-acute rehabilitation, including insurance companies, other payer sources, and program financiers. Finally, this area of study benefits society at large in that research-informed improvement of post-acute interventions should lead to a less disabled, more productive, society-contributing population of ABI survivors.

Defining Post-Acute Brain Injury Rehabilitation

In their review of post-acute brain injury rehabilitation studies, Malec and Basford (1996) defined the following levels of brain injury rehabilitation: (1) *acute rehabilitation* is defined as the initial in-hospital multidisciplinary rehabilitation process that focuses on medical stability and physical rehabilitation and initiates cognitive and behavioral rehabilitation; (2) *subacute rehabilitation* is defined as residential care (i.e. coma management or behavioral management) for individuals who are unable to participate in more intensive rehabilitation due to severe cognitive or behavioral deficits; and (3) *post-acute brain injury rehabilitation* is defined to include a number of specialized programs appropriate for individuals able to benefit from further rehabilitation beyond acute/subacute rehabilitation.

Malec and Basford go on to further delineate four classes of post-acute brain injury rehabilitation programs that have been described and evaluated in the scientific literature: (1) *neurobehavioral programs* are behavioral programs that provide intensive behavioral treatment to brain injury patients with severe behavioral impairments; (2) *residential community re-integration programs* provide integrated cognitive, emotional, behavioral, physical, and vocational rehabilitation to patients who cannot participate in outpatient programs either because of severe cognitive and behavioral impairments or the unavailability of outpatient services; (3) *comprehensive (holistic) day treatment programs* offer integrated, multimodal rehabilitation with an emphasis on improvement in self-awareness, as described originally by Ben-Yishay and Prigatano (1990); and (4) *outpatient community re-entry programs*, which typically focus on social and vocational reintegration.

While the philosophy or orientation of some rehabilitation programs may be generally consistent with a specific class of post-acute rehabilitation as defined by Malec and Basford, others resemble a hybrid of philosophies or treatment orientations. For example, some programs incorporate distinct "tracks" of care which incorporate aspects from different philosophies within one unitary program, where each patient is either classified into one track or moves amongst tracks, depending on his or her evolving goals across the rehabilitation continuum. Moreover, a review of the literature suggests that there is significant variability even amongst programs with similarly "named" philosophies. Thus, one can begin to appreciate the broad range of programs that may fall under the umbrella of "post-acute brain injury rehabilitation." Despite this variability, there are several integral commonalities that unite these classes of post-acute rehabilitation programs: 1) the use of highly individualized treatment plans that integrate cognitive and interpersonal interventions; 2) the implementation of these interventions by a transdisciplinary treatment team; and 3) an overall emphasis on comprehensively and holistically addressing multiple aspects of dysfunction within a single treatment setting. For our purposes, the acronym "PABIR," standing for "post-acute brain injury rehabilitation," shall refer to treatments provided by programs that share these essential characteristics, regardless of which Malec and Basford class (or hybrid of classes) they fall into. Thus, PABIR programs are distinguished from multidisciplinary, non-integrative, post-acute rehabilitation interventions, in which different disciplines may treat their respective aspects of dysfunction simultaneously, but in relative isolation from other disciplines.

No matter the structure of a particular PABIR program, the end goal remains the same: to promote an outcome that results in the individual with ABI acquiring an overall sense of functional independence and productive community functioning that ultimately results in a positive quality of life (Evans, 1997). In terms of the World Health Organization (WHO) International Classification of Functioning, Disability, and Health (ICF), this corresponds to improvements at both the level of *activity* (i.e. disability) and *participation* (i.e. handicap; World Health Organization, 2001). PABIR aims to reduce disability and improve social participation through the treatment of the complex cognitive, social, and behavioral problems associated with brain injury through the extended period of recovery (Harrick, Krefting, Johnston, Carlson, & Minnes, 1994). Harrick and colleagues (1994) purport that, in order to do this, PABIR must provide the appropriate level of support at each stage of the individual's recovery, while exposing the individual to as many real-life situations as possible. In providing this therapeutic environment in which mistakes can be safely made, the PABIR model is designed to improve motivation for change by fostering awareness of one's deficits and their implications (Ben-Yishay & Prigatano, 1990). An additional challenge of PABIR is to ensure maximum generalization of gains made within the therapeutic environment to the home, community, and/or work setting (Cope et al., 1991a).

Methodological Issues in PABIR Research

Researchers investigating the effectiveness of PABIR continue to face a number of methodological challenges, as summarized by Harrick and colleagues (1994): (1) lack of consensus on defining severity of injury (SOI); (2) a heterogeneous client population; (3) lack of standardized outcome measures; and (4) lack of adequate comparison groups. Though almost twenty years have passed since the publication of their article, Harrick and colleagues outlined a number of issues that are still prevalent today. While many researchers have begun to address these limitations, a thorough discussion of each of these methodological obstacles is presented in the subsequent sections.

Defining Severity of Injury

Determining the severity of an ABI is a multifaceted process that begins long before an individual presents for PABIR. A TBI is typically classified – at some point during the initial hours, days, or weeks of recovery – as either mild, complicated mild, moderate, or severe in nature. This clinical judgment of TBI severity is ideally based on an amalgamation of information from a number of sources including level of consciousness (e.g. measured by the Glasgow Coma Scale [GCS]; Jennett & Bond, 1975), length of coma, the length of post-traumatic amnesia (PTA), and the nature and extent of damage to the brain tissue as determined by neuroimaging (Lezak, Howieson, & Loring, 2004, p.160). Unfortunately, protocols for collecting and recording SOI indicators in TBI patients vary widely from hospital to hospital, and sometimes pertinent information is not well documented (H. J. Hannay, personal communication, August 15, 2008). For example, a GCS score with no indication of when it was determined and the status of other pertinent variables at the time (e.g., clinical signs, blood alcohol level and level of recreational or prescribed drugs, sedation for agitation, intubation, etc.) can lead to an inaccurate assessment of the severity of an injury (Lezak, Howieson, & Loring, 2004, p.160).

Similar issues arise with regards to CVA severity classification. Spilker and colleagues (1997) noted that widely-used neurological assessment tools (e.g., GCS) document disturbances in consciousness rather that the focal neurological deficits often seen in stroke patients. They recommend that the NIH Stroke Scale, originally developed as a research tool, be used clinically to assess the extent of neurological deficits seen in acute stroke patients. However, the percentage of clinical institutions that have adopted the use of standardized measures such as the NIH Stroke Scale and other similar tools is unknown. It is our observation that, in practice, the severity of a stroke may be informally determined through clinical judgment based on the type and extent of CVA, size and location of the lesion, extent of acute focal neurological deficits, level of functional impairment, and/or rate of functional recovery over time.

For TBI and stroke patients alike, severity classification issues are only magnified at the post-acute level of care, as acute medical records may be incomplete, unclear, or unattainable, particularly for those patients who present for care months, or even years, post-injury. This ongoing challenge is reflected in the often vague (or absent) descriptions of the severity of TBI and stroke samples in PABIR outcome research.

Some clinicians and researchers have proposed alternative methods for estimating SOI at the post-acute level when acute SOI indicators are not known. For example, it is fairly common practice to interview patients and family members to obtain estimates of length of coma and PTA in order to assist in estimating SOI; however, this practice is necessarily problematic because family and patient reports are not always accurate and may conflict with one another. Sherer and colleagues used demographic information (e.g., age, education) and available injury severity indicators (e.g., GCS scores, pupillary response) to create linear regression models that provide estimates of length of coma and PTA for TBI patients (Sherer, Struchen, Yablon, Wang, & Nick, 2008). These estimation methods may be useful both clinically and research-wise when information regarding length of coma and PTA is unknown.

Alternatively, when initial SOI indicators are unknown and inestimable, a thorough assessment of the extent of functional deficits present upon entry into PABIR may be used to estimate, to some extent, the unknown SOI (Cope et al., 1991a; Klonoff, Lamp, Henderson, & Sheperd, 1998). While a measurement of severity of deficit (SOD) at the time of admission to PABIR cannot substitute for traditional measurement of SOI, knowledge of an individual's SOD is always useful for the purposes of PABIR treatment planning. As well, the statistical control of SOD can be used to account for individual differences in the functional level between patients when they enter the treatment program. As an example, Cope et al. (1991a) used the individual's Disability Rating Scale (DRS; Rappaport, Hall, Hopkins, Belleza, & Cope, 1982) scores at admission, considered in the context of time since injury (TSI), as an approximation of SOI used for statistical control. In contrast, Klonoff et al. (1998) created a "functional severity index" that utilized a 10 point scale (1=severe, 10=mild); ratings were derived through staff consensus based on the observed severity of cognitive, physical, speech/language, and behavioral deficits present in the first few weeks of participation in PABIR. These and similar methods that estimate SOD are not uncommon in PABIR research, but should be distinguished from those that attempt to estimate SOI based on traditional SOI indicators (as described in the previous paragraph).

Accurate SOI is important at the post-acute level of care for several reasons. SOI has been shown to be one of the most important predictors of outcome from TBI, if not the most important (Cohadon, Castel, Richer, Mazaux, & Loiseau, 2002; Levin, 1985; Richardson, 2000). It is likely that SOI is also highly related to outcome from others forms of ABI (e.g., stroke, anoxic injury), though this has not been as widely studied. This means that, from a clinical standpoint, knowledge about an individual's SOI is often instrumental in generating prognostic hypotheses and informing treatment recommendations (Cohadon et al., 2002; Levin, 1985; Richardson, 2000). Expectation of "successful" outcome may vary greatly depending on the SOI (Cope et al., 1991a), and the individual's SOI is typically related to the specific nature of his or her rehabilitation goals (e.g. return to work versus independence in basic self care). From a research standpoint, control of SOI in PABIR studies can help researchers determine the unique effect of rehabilitation on outcome above and beyond that which is accounted for by SOI.

Heterogeneity of Client Population

Individuals with ABI who present for PABIR may vary greatly with regards to etiology of injury, SOI, and TSI upon admission to post-acute rehabilitation. These variables, among others, are often related to the individual's unique presentation of neurobehavioral symptomatology (and consequently individualized goals), and thus must be carefully accounted for in PABIR research. The heterogeneity of the ABI population has not been addressed consistently across PABIR studies, as samples thus far have been variable with regard to the exclusion of persons with etiologies other than TBI, the characterization and control of SOI, and the range of post-injury intervals included (Sander, Roebuck, Struchen, Sherer, & High, 2001).

Etiology. It is becoming common practice to treat patients with various etiologies in the PABIR setting; this has led to the etiological diversification of patient samples in PABIR research. Many studies and systematic reviews chose to focus on the effectiveness of rehabilitation specifically for those with TBI (excluding those with non-TBI etiologies from their study sample) in an effort to isolate a more homogenous population. However, even reviews that attempt to isolate TBI patients often include diverse samples. For example, a recent review examining the effectiveness of multidisciplinary post-acute rehabilitation for moderate-to-severe TBI, included studies with samples consisting of *at least* 75% moderate-to-severe TBI patients (Brasure et al., 2012). While practices such as these are understandable due to the great diversity in individuals presenting for PABIR, they lead to non-negligible inclusion of diverse populations which may confound results relevant to the population of interest. Alternatively, other researchers deliberately choose to consider all ABI patients in their analyses, reasoning that the clinical courses of TBI, CVA, and other types of ABI are similar, regardless of etiology - beginning with either a focal or diffuse impairment of brain function, progressing through a period of physiological reorganization and functional recovery, and usually plateauing at a stable level of functioning (Boake, Francisco, Ivanhoe, & Kothari, 2000). While this approach may lead to greater generalizability of findings, it is problematic in that TBI patients are inherently different from other types of ABI patients. As one example, stroke patients are typically older and more likely to suffer from comorbid health conditions (e.g., hypertension, diabetes, heart disease) than TBI patients (Jager, Weiss, Cohen, & Pepe, 2000; Richardson, 2000), which may make these patients vulnerable to poorer outcome. Further research is needed to determine if etiology itself or etiology-related factors (e.g., age, comorbid health conditions) are uniquely associated with outcome following PABIR.

Severity of injury. PABIR client populations can vary greatly with regards to SOI, and the severity composition of the study sample must be carefully considered when interpreting the implications and generalizability of reported findings. Some researchers exclude patients who do not meet a particular severity criteria (e.g. participants must be classified as having had a severe TBI), while others include patients of all severities in their sample and control for SOI quantitatively. This distinction is important because the percentage of the sample that is severely injured may greatly affect the results observed. For example, studies with samples strictly made up of patients with severe TBI report much lower rates of return to work than those with samples that included patients with moderate and mild TBI as well (Eames & Wood, 1985; Malec, Smigielski, DePompolo, & Thompson, 1993). Thus, it is imperative for PABIR researchers to describe and take into account SOI, as this will greatly influence the reader's interpretation and generalizability of reported findings.

Time since injury. TSI upon admission to PABIR can range drastically, from several weeks to many years post-injury (often with great variability within a single study). TSI intervals are relevant to PABIR research because it is well accepted that a certain amount of recovery will occur spontaneously, as a result of natural physiological repair, during the early post-injury phases (Nudo, 2006; Nudo, 2011; Swaine & Sullivan, 1996). Thus, it follows that one would expect greater cumulative gains in those who are earlier in their recovery course relative to those who are further post-injury. The most ideal way to dissociate the effect of rehabilitation from spontaneous recovery is through inclusion of an appropriate no-treatment control group. Unfortunately, this is often unfeasible, and so researchers have attempted to methodologically and statistically account for TSI in other ways. Some researchers separated their sample into subgroups based on TSI (e.g., less than and greater than one year post-injury; Benge, Caroselli, Reed, & Zgaljardic, 2010; Coetzer & Rushe, 2005; Cope et al., 1991a; High, Roebuck-Spencer, Sander, Struchen, & Sherer, 2006; Seale et al., 2002; Wood, McCrea, Wood, & Merriman, 1999), while others included TSI as a continuous covariate in their models (Johnston & Lewis, 1991; Klonoff, Lamp, & Henderson, 2000; Sander et al., 2001). Alternatively, others used a TSI inclusion criterion (e.g. must be less than eight months post-injury; Sander et al., 2001).

Outcome Measurement

Lack of a consensus definition of outcome measurement is a well-documented limitation of research in the field of PABIR (Semlyen, Summers, & Barnes, 1998) - one that has become increasingly studied and discussed as the field progresses. Corrigan (1994) observed that outcomes can be defined from the perspective of the individual with ABI, the treating healthcare professionals, or the society in which the individual lives. Although these perspectives may differ, common themes of outcome measurement that appear to span perspectives have emerged in the PABIR literature. Community integration has become one of the core outcome goals of rehabilitation from the perspective of the individual, health professionals, and society (High et al., 2006; Seale et al., 2002; Svendsen & Teasdale, 2006), particularly as more persons with ABI survive and return to their communities becomes a priority. A commonly used definition of community reintegration incorporates three main areas: employment or other productive activity, independent living, and social activity (Willer & Corrigan, 1994). There are a number of additional factors that may mediate one's community reintegration following ABI including level and nature of disability, behavioral and emotional functioning, and psychosocial support, and cultural factors. Over time, our understanding of these constructs and methods of measuring them has evolved.

Pioneers in the field of PABIR research did not have access to well-defined, reliable, and valid outcome assessment tools. Therefore, many earlier researchers defined outcome variables idiosyncratically. For example, some studies defined a successful vocational outcome as a return to competitive (gainful) employment, while others considered return to other forms of productive activity –

such as supported employment, volunteer work, or homemaking – when defining vocational outcome. Similarly, with regard to independent living status, Cope and colleagues (1991a) catalogued hours of assistance required, while Johnston and Lewis (1991) described a five-point scale indicating hours of supervision and assistance required. These are only a few examples of the great variation among outcome measurement techniques in brain injury rehabilitation research. Authors of these earlier studies have noted that more comprehensive and/or multiple outcome measures would provide a more detailed picture of outcome after participation in PABIR (Cope et al., 1991a; Johnston & Lewis, 1991).

As the field has progressed, the standardization of a number of valid and reliable outcome measures has provided greater confidence in results and ease of comparison across studies. Rehabilitation outcome measures can be broadly separated into two categories, consistent with the WHO ICF model: 1) those focused on outcomes at the level of impairment in activity (i.e. disability), and 2) those focused on outcomes at the level of participation and personal context (e.g., psychosocial adjustment, quality of life). Examples of standardized measures that focus on impairment or capacity to engage in certain activities include the Glasgow Outcome Scale (GOS; Jeanette & Bond, 1975), Disability Rating Scale (DRS; Rappaport et al., 1982) and Functional Independence Measure (FIM; Guide for the Uniform Data Set for Medical Rehabilitation, 1997). Examples of measures that focus on ability to perform certain social roles (e.g. participation) include return-to-work measures, the Community Integration Questionnaire (CIQ; Willer, Rosenthal, Kreutzer, Gordon, & Rempel, 1993), and the Craig Handicap Assessment and Reporting Technique (CHART; Whiteneck, Charlifue, Gerhart, Overhosler, & Richardson, 1992). Other measures, such as the Brief Symptom Inventory 18 (BSI-18; Derogatis, 2001) and the Satisfaction With Life Scale (SWLS; Diener, Emmons, Larsen, & Griffin, 1985), focus on psychosocial adjustment and quality of life, respectively. The development of standardized brain injury outcome measures consistent with the ICF model of health function and dysfunction has been an important progression in the field of PABIR research. The future now lies in determining the best set of outcome measures that should be used consistently in rehabilitation research to capture the wide range of changes that can occur during rehabilitation, in order to facilitate more accurate and direct comparison between outcome studies. In a recent publication by the common data elements (CDE) TBI Outcomes Workgroup, 12 domains that should be assessed in rehabilitation research are outlined: global outcome, recovery of consciousness, neuropsychological impairment, psychological status, TBI-related symptoms, behavioral function, cognitive activity limitations, physical function, social role participation, perceived generic and disease-specific health-related quality of life, health economic measures, and patient-reported outcomes (Wilde et al., 2010). The workgroup proposed a set of core, supplemental, and emerging measures that span these 12 domains and recommended a movement toward uniformity in outcome measure selection. However, the field is still in the beginning stages of this movement, which will likely evolve as more is learned about how to best capture outcome through use of standardized measures.

An additional aspect of outcome measurement that must be considered is the timing of outcome assessment. Ideally, assessments are conducted upon admission to a program, at discharge, and at some follow-up point(s) post-discharge, in order to best assess for gains made during the course of rehabilitation and maintenance of gains following the conclusion of treatment. Unfortunately, some studies lack the data points necessary to assess for gains made during rehabilitation or maintenance of gains after treatment ends. For example, studies that collect data at admission and discharge only are able to postulate that gains made occurred during the isolated time that the individual was participating in rehabilitation, but they are unable to provide information about maintenance of gains or longer-term outcomes of ABI patients who participated in PABIR. Conversely, studies that collect data at admission and at some variable time point post-discharge, but lack a discharge data point, are able to provide information about the long-term outcomes of these individuals, but cannot state with confidence that observed gains were made during the course of rehabilitation. Thus, studies that include an admission, discharge, and at least one follow-up time point provide the richest information about treatment effects, maintenance of gains, and long-term benefits of PABIR. Finally, it is critical to be aware of the great variability in timing of follow-up outcome assessment. Studies report data collected anywhere from one month to fifteen years post-discharge, sometimes with great variation even within a single study. It has been suggested that a consensus be reached regarding the recommendation of standardized outcome measurement time points to allow for more accurate comparison across studies (e.g., six, 12, and 24 months post-discharge; Sander et al., 2001).

Lack of Adequate Comparison Group

Lack of a comparison group makes it impossible to fully dissociate the effect of treatment from spontaneous recovery (Sander et al., 2001). In an effort to address this limitation, some researchers have attempted to control for the variance in outcome attributable to spontaneous recovery by accounting for TSI through study design and/or statistically, as described previously. While this provides more confidence in the conclusion that at least part of the gains observed can be attributed to treatment effects, it does not rule out other causes for change in the way that a RCT design would (Sander et al., 2001).

Consensus within the research community suggests that RCTs are the "gold standard" through which treatment efficacy is demonstrated, as the RCT controls for biases better than other methodologies (Katz et al., 2001; Whyte, 2002). Heterogeneity of patients, rehabilitation services, and outcomes, however, pose a challenge to traditional interventional or RCT-based methodologies (Turner-Stokes, Nair, Sedki, Disler, & Wade, 2011). Moreover, there is an inherent difficulty in randomizing ABI patients to experimental and controlled groups (Teasell et al., 2007). High et al. (2006) argued that enough evidence exists for the efficacy of PABIR programs such that most practitioners would have ethical difficulties with creating a no-treatment comparison group. Thus, the field of brain injury rehabilitation has lagged behind other medical disciplines in the implementation of RCTs to demonstrate efficacy. Despite these challenges, there is a definite push towards higher quality research design in the field of brain injury rehabilitation, as evidenced by more recent reviewers' tendency to include only high-quality RCTs or controlled observational studies in their systematic reviews.

That being said, prospective data from rehabilitation programs lacking a control group may still have a place within the literature. In drug trials, observational studies (Phase II) typically precede randomized control studies (Phase III). Similarly, observational studies of brain injury rehabilitation can help guide future research and form specific questions to be addressed by RCTs. Thus, some might argue that evidence put forth by non-experimental and/or uncontrolled clinical trials, although generally inferior to RCTs, is nevertheless a contributing source of research evidence (Teasell et al., 2007).

The Efficacy of PABIR

The literature on the efficacy of PABIR for patients with TBI and other types of ABI remains inconclusive. This is not due to a lack of published research studies, but rather to inconsistency of findings across studies. Multiple systematic reviews have been conducted and have yielded conflicting conclusions about the efficacy of PABIR. This is likely due to differences in methodological decisions about which populations, outcomes, and study designs to include across reviews. For example, some reviews included only studies examining rehabilitation outcomes for TBI survivors, while others included studies examining outcomes for a heterogeneous group of ABI patients. Likewise, the evidence grade of included studies differs between reviews, as does the emphasis on particular outcome domains. Moreover, few reviews focus explicitly on transdisciplinary, comprehensive-holistic, post-acute programs, as we have defined "PABIR" for our purposes. Several reviews examine "multidisciplinary" rehabilitation (Bettger & Stineman, 2007; Brasure et al., 2012; Turner-Stokes et al., 2011), which, by definition, may include comprehensive-holistic PABIR programs, but may also include other non-comprehensive multidisciplinary programs. Another review examining the efficacy of cognitive rehabilitation therapy for different domains affected by brain injury (e.g., attention, memory) included a section about the efficacy of "multi-modal" or "comprehensive" cognitive rehabilitation (Institute of Medicine, 2011). We must also re-emphasize the great variability found among rehabilitation programs even with the same descriptive title, which complicates the issue even further. Finally, reviews differed in the extent to which they distinguished post-acute interventions from acute interventions, with some including only post-acute studies (Bettger & Stineman, 2007; Brasure et al., 2012; Cicerone, 2004; Malec & Basford, 1996), and others including acute and post-acute studies (Cicerone et al., 2000; Cicerone et al., 2005; Cicerone et al., 2011; Institute of Medicine, 2011; Turner-Stokes et al., 2011). What follows is a broad overview of the rehabilitation literature that we feel is relevant to answering the question of PABIR efficacy. We have focused our literature review specifically on the efficacy of PABIR for TBI and stroke patients, as these are the two largest subgroups of ABI patients that present for PABIR. Systematic reviews are considered to be the highest level of evidence (Cook, Guyatt, Laupacis, Sackett, & Goldberg, 1995); thus, we provide a synopsis of the conclusions from select systematic reviews over the past 15 years, with heavier emphasis placed on more recent reviews with stringent inclusion criteria regarding study design.

The Efficacy of PABIR for TBI

Malec and Basford (1996) compared results from a number of primarily non-controlled, observational studies of PABIR outcomes to results from brain injury outcome studies in which post-acute intervention was not studied. While the target population was patients with TBI, actual sample composition ranged from 48% to 100% TBI across studies. Following post acute rehabilitation, 71% of 856 subjects were engaged in productive vocational activity (sheltered workshop; volunteer; supported work; independent work, school, or homemaking), whereas 53% of 796 subjects who received no, unspecified, or only inpatient rehabilitation were engaged in productive vocational activity. The authors concluded that available research was sufficiently encouraging to recommend more carefully controlled randomized studies.

Cicerone and colleagues (Cicerone et al., 2000; Cicerone et al., 2005; Cicerone et al., 2011) systematically reviewed studies that specifically examined the potential benefits of “comprehensive-holistic cognitive rehabilitation” for both TBI and stroke patients. They rated studies as either Class I (well-designed, prospective, RCT), Class Ia (prospective design with "quasi-randomization"), Class II (prospective, non-randomized cohort studies; retrospective, non-randomized case-control studies; clinical series with well-designed controls that permitted between subjects comparisons of treatment conditions, such as multiple baseline across subjects), or Class III (clinical series without concurrent controls, or studies with results from one or more single cases that used appropriate single-subject methods, such as multiple baseline across interventions with adequate quantification and analysis of results). Thus, while they placed higher value on RCTs and controlled trials, they also took into consideration evidence from non-controlled studies. They excluded studies that were not primarily comprised of either TBI or stroke patients. They considered studies regardless of the SOI of the sample and reported on both acute and post-acute comprehensive-holistic cognitive rehabilitation programs. In their most recent update of the literature (Cicerone et al., 2011) the authors concluded that comprehensive-holistic neuropsychologic rehabilitation can improve community integration, functional independence, and productivity following TBI, even for patients who are many years post injury. The task force specifically recommended post-acute, comprehensive-holistic neuropsychologic rehabilitation as a practice standard (updated from a practice guideline in earlier publications) to reduce cognitive and functional disability after moderate or severe TBI.

Cicerone and colleagues also produced two related review articles examining selected studies from the above larger reviews in an effort to answer more specific questions about outcome after PABIR. In the first related publication, Cicerone (2004) reviewed two Class II studies (Cicerone, Mott, Azulay, & Friel, J. C., 2004; Goranson, Graves, Allison, & La Freniere, 2003) and two Class III studies (Malec, 2001; Seale et al., 2002) that specifically examined participation, or community reintegration, following comprehensive-holistic cognitive rehabilitation for TBI. Patients with mild, moderate, and severe TBI were collectively included across these four studies of post-acute rehabilitation (in both the inpatient and outpatient setting). Cicerone concluded that these studies collectively suggest that comprehensive, post-acute TBI rehabilitation is capable of producing significant improvements in community integration and social participation. There was also evidence that rehabilitation may have differential impact on different aspects of participation. For example, benefits in several studies were most apparent on the performance of everyday activities within the home, with less effect on participation in social activities and interpersonal relationships. Also, it was noted that post-acute, comprehensive TBI rehabilitation may have the benefit of not only producing improvements in community functioning, but also in preventing significant declines in functioning.

The second related review by Cicerone and colleagues (Cicerone, Azulay, & Trott, 2009) was a secondary analysis of select higher quality studies identified in prior systematic reviews. Study quality was determined based on a checklist of criteria adapted from the checklist developed by Turner-Stokes and colleagues (Turner-Stokes, Disler, Nair, & Wade, 2005), based on the prior work of van Tulder (van Tulder, AFurlan, Bombardier, & Bouter, 2003). Sixteen primary criteria were identified: eight internal validity criteria, five descriptive criteria, and three statistical criteria. Studies selected for the review of comprehensive-integrated cognitive rehabilitation included one RCT (Salazar et al., 2000) and four high quality, non-RCT studies (Cicerone et al., 2004; Goranson et al., 2003; Rattok et al., 1992; Sarajuuri et al., 2005). Cicerone and colleagues concluded that while the RCT did not suggest effectiveness of comprehensive-holistic cognitive rehabilitation for military service personnel with milder injuries[1], results from the four high quality observational studies support the effectiveness of comprehensive-holistic rehabilitation after TBI, including improvements in participation outcomes. Thus, even after excluding evidence from lower quality studies, Cicerone and colleagues reached a similar conclusion to those drawn in prior systematic reviews.

Publications by Cicerone and colleagues have been cited frequently as demonstrating evidence for the efficacy of comprehensive-holistic cognitive rehabilitation for individuals with moderate-to-severe TBI. However, other recent systematic reviews vary in the degree to which they make similar conclusions. Turner-Stokes and colleagues (2011) recently published a systematic review of the efficacy of multidisciplinary rehabilitation following ABI in working age adults. Multidisciplinary rehabilitation was defined as any intervention delivered by two or more disciplines working in coordinated effort. The authors included studies from inpatient settings, outpatient or day treatment programs, and home-based programs at the both the acute and post-acute level of care. They relied heavily on evidence from RCTs. The three primary conclusions of the review were as follows: 1) results from five high quality RCTs (Elgmark, Emanuelson, Björklund, & Stålhammar, 2007; Paniak, Toller-Lobe, Durand, & Nagy, 1998;

[1] Though the sample in this study was described by the authors as individuals with "moderate-to-severe closed head injury," the following suggests that the sample as a whole was functioning at a higher level than that of most patients with moderate-to-severe TBI: (1) more impaired persons may have been excluded from the study by the inclusion criterion of "active military duty, not pending medical separation;" (2) six of seven subjects who withdrew prematurely from the hospital program were also employed and fit for duty at 1 year; and (3) the employment outcomes in this study are substantially greater than those shown in other studies of persons participating in rehabilitation. Additionally, many have pointed out that the use of an active duty military population limits generalizability to the typical rehabilitation program (Sander et al., 2001).

Salazar et al., 2000; Wade, Crawford, Wenden, King, Moss, 1997; Wade, King, Wenden, Crawford, & Caldwell,1998) suggested that multidisciplinary intervention was not effective for milder, ambulatory TBI patients compared to the control interventions, presumably because most mild patients make good recoveries with or without treatment; 2) there was a subgroup of TBI patients from these five RCTs with moderate-to-severe injury who benefited from multidisciplinary intervention; and 3) several high quality studies (Shiel et al., 2001; Slade, Tennant, & Chamberlain, 2002; Zhu, Poon, Chan, & Chan, 2007) provided strong evidence that more intensive rehabilitation programs are associated with earlier functional gain for moderate-to-severe TBI patients once patients are fit to engage. Thus, these conclusions are compatible with those provided by Cicerone and colleagues (Cicerone, 2004; Cicerone et al., 2000; Cicerone et al., 2005; Cicerone, Azulay, & Trott, 2009; Cicerone et al., 2011) – namely, that individuals with moderate-to-severe TBI benefited from intensive multidisciplinary or comprehensive-holistic cognitive rehabilitation (whereas those with milder injuries did not). Of note, a primary difference in study inclusion criteria between reviews by Cicerone and colleagues and the review by Turner Stokes and colleagues (2011) is the inclusion of studies with any intervention delivered by two or more disciplines working in coordinated effort in the latter review. While comprehensive-holistic programs are considered multidisciplinary (and would thus meet this criteria), not all multidisciplinary programs would be considered comprehensive-holistic.

In contrast, a recent systematic review by the Institute of Medicine reached a different conclusion (Institute of Medicine, 2011). The authors reviewed six RCTs (Cicerone et al., 2008; Ruff & Neimann,1990; Salazar et al., 2000; Tiersky et al., 2005; Vanderploeg et al., 2008; Zhu et al., 2007) and seven non-randomized controlled trials (Bowen, Tennant, Neumann, & Chamberlain, 1999; Chen, Thomas, Glueckauf, & Bracy, 1997; Cicerone et al., 2004; Goranson et al., 2003; Middleton, Lambert, & Seggar, 1991; Parente & Stapleton, 1999; Sarajuuri et al., 2005) of multimodal or comprehensive cognitive rehabilitation therapy for samples primarily involving TBI patients. Four studies took place in the “subacute” phase (between 3 and 6 months post-injury) and nine studies took place in the “chronic” phase (greater than 6 months post-injury). The authors developed the following evidence grading system:

not informative (intervention not studied, null results, or positive results from a flawed study); *limited* (interpretable result from a single study or mixed results from two or more studies); *modest* (two or more studies reporting interpretable, informative, and largely similar results); or *strong* (reproducible, consistent, and decisive findings from two or more independent studies). The authors provided conclusions regarding the efficacy of multimodal or comprehensive cognitive rehabilitation at both subacute and chronic stages of recovery from TBI. Within the subacute phase, evidence was *not informative* regarding the efficacy of comprehensive cognitive rehabilitation therapy on person-centered outcomes (e.g., quality of life, functional outcome) or the sustainment of treatment effects, regardless of SOI. Within the chronic phase of recovery, evidence was *limited* regarding the efficacy of comprehensive cognitive rehabilitation therapy on person centered outcomes or the sustainment of treatment effects for mild TBI patients, and *not informative* for moderate to severe TBI patients. The authors stated that the lack of large trials with an inert or waitlist comparison group was the primary reason for their conclusions.

Another recent systematic review examining the effectiveness and comparative effectiveness of multidisciplinary post-acute rehabilitation for moderate to severe TBI in adults, reached similar conclusions (Brasure et al., 2012). This particular review placed emphasis on selected patient-centered participation outcomes of productivity and community integration, restricted its review to studies of moderate-to-severe TBI, and drew heavily from RCTs and prospective cohort controlled studies. The authors first assessed each study for risk of bias using assessment forms developed specifically for this project. For RCTs, they modified the Cochrane Risk of Bias Tool by adding items to capture potential risk of bias specific to this topic. Additional items were from the Response to Intervention (RTI) Observational Studies Risk of Bias and Precision Item Bank. The authors also created a risk of bias assessment form for observational studies by selecting items from this item bank that corresponded to those in the modified Cochrane tool. Investigators assigned summary scores of low, moderate, or high, based on their judgment about the collective risk of bias. The authors then evaluated the overall strength of evidence (SOE) for eligible studies for each primary outcome or comparison using methods developed by the Agency for Healthcare Research and Quality (AHRQ) and its Effective Health Care Program (they did not include studies with a high risk of bias when determining SOE). Authors evaluated SOE based on four required domains (risk of bias, consistency, directness, and precision). Authors rated the overall evidence for each outcome and comparison as *high*, *moderate*, *low*, or *insufficient*. This review included studies of post-acute intervention that were multidisciplinary in nature and occurred in inpatient, outpatient, or home/community-based settings. Studies were included if the sample was comprised of at least 75% moderate-to-severe TBI. The authors concluded that currently available evidence was *insufficient* to draw conclusions about the effectiveness of multidisciplinary post-acute rehabilitation for moderate-to-severe TBI.

To summarize, there is a lack of consensus regarding the efficacy of PABIR for TBI patients. Reviews that considered lower quality sources of evidence (e.g. non-controlled observational studies) in addition to RCTs and other high-quality controlled trials, concluded that post-acute rehabilitation for TBI patients resulted in reduced disability and improved social integration and community participation, particularly for those with moderate-to-severe injuries (Cicerone et al., 2000; Cicerone, 2004; Cicerone et al., 2005; Cicerone et al., 2011; Malec & Basford, 1996). While the conclusions of two reviews with more stringent methodological inclusion criteria supported these findings (Cicerone, Azulay, & Trott , 2009; Turner-Stokes et al., 2011), two recent reviews that relied heavily on RCTs reported inconclusive findings to date regarding the efficacy of post-acute multidisciplinary rehabilitation for TBI (Brasure et al., 2012; Institute of Medicine, 2011). One possible explanation for discrepancies is that Cicerone and colleagues specifically included studies that were not just multidisciplinary in nature, but deemed to be comprehensive-holistic cognitive rehabilitation, whereas other reviews (Brasure et al., 2012; Institute of Medicine, 2011; Turner-Stokes et al., 2011) included any rehabilitation that was “multidisciplinary.” For example, Brasure et al. (2012) included home and community-based post-acute interventions that were not included in reviews by Cicerone and colleagues. As another example, the Institute of Medicine included studies of computer administered (yet multimodal) cognitive therapy (Chen et al., 2007; Middleton , Lambert, & Seggar, 1991) that clearly are not “programs” of comprehensive-holistic PABIR.

Thus, future reviews should aim to carefully include only trials of post-acute rehabilitation programs that explicitly strive to be not only transdisciplinary, but comprehensive, integrative, and holistic in nature.

The Efficacy of PABIR for Stroke Patients

Unlike TBI rehabilitation research, there is no shortage of RCTs in the stroke intervention literature. Unfortunately, it has been noted that, as a whole, the existing body of stroke intervention research fails to distinguish acute medical management from post-acute rehabilitation and lacks explicit descriptions of treatment settings and protocols (Rice-Oxley & Turner-Stokes, 1999). A recent comprehensive review of the stroke rehabilitation literature (which drew heavily from conclusions of past systematic reviews and RCTs) concluded that multidisciplinary stroke-unit care is recommended to improve independence (Langhorne, Bernhardt, & Kwakkel, 2011). However, this conclusion was not specific to the post-acute level of care, and presumably reflects, in large part, results from RCTs conducted at the acute care level. Bettger and Stineman (2007) integrated the results from several systematic reviews of specifically post-acute (i.e., delivered after acute hospitalization), multidisciplinary rehabilitation for stroke patients. They concluded that there was strong evidence supporting the benefits of post-acute rehabilitation for stroke patients. Specifically, subjects who received “focused stroke rehabilitation” had better functional outcomes and increased odds of going home. Outpatient therapy-based rehabilitation services were also shown to reduce the odds of a decline in activities of daily living (ADLs) at 6 months, compared with conventional or no care. However, it is not clear if these multidisciplinary “focused stroke rehabilitation” programs were comprehensive-holistic in nature, or simply implemented by a multidisciplinary team with an emphasis on stroke specific deficits.

A number of the reviews discussed previously that examined multidisciplinary and/or comprehensive cognitive rehabilitation for TBI also provided conclusions regarding the efficacy of such programs for stroke survivors. In Cicerone and colleagues’ (2005) first update of the cognitive rehabilitation literature, they extended their recommendation for post-acute comprehensive-holistic neuropsychologic rehabilitation to include stroke as well as TBI patients. This was based on evidence from four Class III studies (Malec, 2001; Sander et al., 2001; Seale et al., 2002; Klonoff et al., 1998) with

265 subjects that collectively supported the clinical effectiveness of comprehensive-holistic programs for improving community integration, social participation, and productivity after both TBI and stroke. Similarly, Turner-Stokes et al. (2011) made the following two conclusions about the effectiveness of multidisciplinary post-acute rehabilitation for patients with stroke: 1) there was *moderate* evidence that outpatient multidisciplinary therapy following hospital discharge improves outcomes for generally more severe stroke patients compared to no treatment controls; 2) there was *indicative* evidence that this type of intervention may be effective even “late” (i.e., at least 1 year) after stroke.

In sum, there is evidence in support of multidisciplinary rehabilitation for stroke patients in acute and post-acute phases of recovery. However, relatively little research has examined the efficacy of comprehensive-holistic PABIR specifically for stroke patients.

Comparison of Rehabilitation Outcomes for TBI and Non-TBI Patients

Even fewer studies have directly compared post-acute rehabilitation outcomes between TBI and non-TBI patients participating in the same program. Cope and colleagues stated that TBI (in contrast to other forms of ABI such as stroke, anoxia, or encephalitis) was felt by many clinicians to be particularly appropriate for the extended treatment of the post-acute rehabilitation model (Cope, Cole, Hall, & Barkan, 1991b). Research examining this hypothesis has yielded conflicting results. Johnston and Lewis (1991) found that non-TBI patients (n=16) participating in a residential community re-entry program made less gains in supervision compared to TBI patients (n=66); however, groups did not differ in productivity outcomes, which the authors speculated was due to the small sample size of the non-TBI group. A more recent study comparing the outcomes of moderate-to-severe TBI (n=404) versus non-TBI (n=169) after participation in an inpatient neurorehabilitation program, also found support for the hypothesis that TBI patients achieve better functional outcome compared to non-TBI patients (Cullen, Park, & Bayley, 2008). More specifically, TBI patients exhibited greater gain scores and efficiency ratios on the Functional Independence Measure (FIM) motor and cognitive subscales (as evidenced by changes in FIM score/day), as well as lower DRS scores (indicating less disability) at discharge and one year follow-up. In an effort to control for varying pre-injury and injury characteristics, Cullen and colleagues (2008) also performed a case-matched analysis that controlled for age, length of acute care hospital stay, and admission levels of functional impairment. This analysis yielded a similar result, with TBI patients (n=77) achieving significantly lower DRS scores and significantly higher FIM scores at discharge compared to those in the non-TBI group (n=77), reflecting better functional outcome for TBI patients. Similar findings have been reported across studies assessing the mobility recovery of children and youth having ABI, with those in the TBI group showing better motor outcomes compared to those in the non-TBI group (Fragala, Haley, Dumas, & Rabin, 2002; Haley, Dumas, & Ludlow, 2001; Vander Schaaf, Kriel, Krach, & Luxenberg, 1997). In contrast, Gray and Burnham (2000) found that there was no significant effect of etiology on the degree of functional improvement observed in adult ABI patients after controlling for cofounding variables such as age, length of stay, and TSI. Likewise, Cope et al. (1991b) found that outcomes in residential status, productivity, and level of attendant care were similar for TBI and non-TBI patients.

A main drawback to the above studies is that they have compared patients with TBI to “blended” groups of patients with non-TBI, where the latter have various brain etiologies and thus could have very different outcomes and potential for recovery (Smania et al., 2011). A recent study specifically examined differences in characteristics and outcomes between severe TBI and stroke patients who participated in intensive inpatient rehabilitation (Smania et al., 2011). They found that TBI patients were younger, presented for rehabilitation earlier post-injury, showed greater functional and cognitive outcomes, and were more likely to be discharged home compared to patients with stroke. In addition, these investigators found that age, etiology, and admission DRS could aid in the prediction of discharge destinations. It is not clear from this study if rehabilitation was acute versus post-acute, multidisciplinary, or comprehensive-holistic in nature. We were unable to find any studies that compared outcomes of patients with TBI versus stroke following participation in an explicitly defined, comprehensive-holistic PABIR program.

The Current Study

The aim of the current study was threefold. The first aim was to examine the demographic, injury, and clinical characteristics of patients with TBI and stroke who present to the PABIR level of care in a more detailed manner than has been done previously (Aim 1). The second aim was to explore the similarities and differences in rate of functional recovery, cumulative functional gains, and maintenance of gains between patients with TBI and stroke who participated in a residential PABIR program (Aim 2). The third aim was to examine the demographic, injury, and clinical variables that may be differentially related to successful PABIR outcomes in patients with TBI versus stroke (Aim 3).

In the current study, effort was made to address the common methodological limitations of PABIR research. The severity, etiologic, demographic, and injury-related characteristics of our sample was transparently described, in an attempt to address the great heterogeneity of the ABI patient population. Reliable and valid outcome measures that aim to capture a range of aspects of recovery and have been standardized for specific use within the brain injury population were utilized. Outcome measurement was assessed at multiple time points, including admission, discharge, and six-month follow-up. While it was not feasible to include a no-treatment control group, we aimed to create a high-quality non-experimental design study by adhering to the recommendations provided by Downs and Black (1988).

Hypotheses

The following hypotheses were proposed:

- Hypothesis 1a: After adjusting for level of functioning at admission and TSI, both patients with TBI and stroke would make functional gains over time (from PABIR admission to six-month follow-up).
- Hypothesis 1b: Patients with stroke would demonstrate a slower rate of functional change, resulting in less cumulative gains over time relative to TBI patients.

- Hypothesis 2: Patients with TBI would achieve higher levels of reintegration into home and societal roles, be less disabled, and require less supervision relative to patients with stroke at 6 months post-discharge.
- Hypothesis 3: Younger age, higher education, and fewer co-morbid health conditions would be related to positive outcomes from PABIR for both patients with TBI and stroke.

Method

Clinical Program Description

Mentis Neuro Rehabilitation (Mentis) is a post-acute rehabilitation facility located in Houston, Texas that specializes in community re-integration for persons who have sustained an ABI. The rehabilitation program provided through Mentis falls under the umbrella of what we have previously defined as PABIR in that it prioritizes the following: 1) the use of highly individualized treatment plans that integrate cognitive and interpersonal interventions; 2) the implementation of these interventions by a transdisciplinary treatment team; and 3) an overall emphasis on comprehensively and holistically addressing multiple aspects of dysfunction within a single treatment setting, with a focus on improving awareness of deficits and improving overall independence and participation in productive activity at the time of discharge. All program participants warrant a referral for PABIR due to restrictions in mobility, social interaction, communication, employability, and/or re-entry into their homes and communities secondary to an acquired neurological condition. Upon admission to Mentis, individuals undergo comprehensive evaluation in cognitive, behavioral, physical, emotional, and social functioning. Individualized treatment programs designed to target specific personalized goals are then developed with the aim of decreasing the impact of these impairments on daily functioning. The treatment program is carried out cooperatively by a transdisciplinary team consisting of physiatry, neuropsychology, physical therapy, occupational therapy, speech and language pathology, case management, nursing, social work, and vocational therapy. Both individual and group interventions are employed within the treatment facility and/or via community outings, depending on the needs of the individual. Family participation and education are considered an integral part of the rehabilitation process and are facilitated through transdisciplinary family conferences, discipline-specific family consultations, home and work assessments, family rounds, and the provision of family support groups and formal educational classes by the treatment staff.

The TBI and stroke patients in this study all participated in the residential program (RP) at Mentis. Patients in the residential program reside within the facility and take part in facility- and/or community-based therapy (individual and group) for an average of five to six hours per day, five days per week. There are also opportunities to participate in activities in the evening hours as part of a community environment that fosters socialization and re-establishment of pre-injury routines. Additionally, a subgroup of Mentis residents transition into comprehensive outpatient therapy (five to six hours per day, two to three days per week), provided by the same transdisciplinary team, prior to final discharge from the treatment program (we will refer to this group as the “residential plus program” group or RP+). The RP+ treatment continuum represents a transitional model designed to maximize generalization of gains made in the therapeutic setting to home, community, and work/school settings.

Goals of Mentis’ RP and RP+ include, but are not limited to: (1) teaching compensatory strategies to address residual cognitive deficits while promoting awareness of such; (2) arranging environmental supports to maximize functioning; (3) increasing mobility both within the home and the community; (4) improving independence in both basic and instrumental activities of daily living; (5) supportive counseling and education to participants and their families/significant others to address emotional adjustment, relationship issues and to facilitate adaptive coping strategies, while improving self-awareness of deficits; and (6) transition from simulated activities in the therapeutic setting to productive activities in the community, among others. Goals are personalized with input from the individual with ABI and their families to ensure that they target important areas in the patient’s life and community.

Participants

Participants in the present study were derived from 176 patients with TBI or stroke who were admitted to Mentis between May 27th, 2008 and April 3rd, 2012. Participants were excluded from the study sample if they were deemed to have not participated in the program (N=8), were medically discharged (N=6), or were discharged against medical advice (N=7). An additional 31 individuals were missing six month follow-up data and thus were excluded from this study. Of these 31 individuals, two were deceased, four re-entered the program within six months of discharge, and 25 were lost to follow-up. Finally, individuals were excluded if they were more than two years post-injury at the time of their admission (N=10).[2] This yielded a study sample of 114 participants (72 patients with TBI; 42 patients with stroke). Of the 114 study participants, 67 patients were from the RP and 47 were from the RP+. Please see Table 1 for a breakdown of the study sample size by etiology (i.e., TBI, stroke) and program type (i.e., RP, RP+).

Outcome Measures

Disability Rating Scale (DRS). The DRS (Rappaport et al., 1982) is a global measure of outcome that is widely used with individuals with brain injury because it is able to capture increments of functional improvement throughout the span of the recovery process (i.e., "from coma to community"). With regards to the ICF model, the DRS quantifies an individual's capacity to perform activities (i.e., impairment or disability). It was recommended by the CDE TBI Outcome Workgroup as a supplemental measure that should be included in TBI research to assess global outcome (Wilde et al., 2010). The DRS consists of eight items corresponding to the following areas of functioning: (1) eye opening; (2) verbalization; (3) motor response; (4) level of cognitive ability for feeding, toileting, and grooming; (5) overall level of independence; and (6) employability. These eight ratings are then summed to give a total score that ranges from zero to 30, with zero representing no disability and 30 representing death; thus lower scores on the DRS are associated with better outcome. See Table 2 for a guideline for interpreting

[2] This exclusion criterion was implemented in an effort to isolate a more homogenous sample with regards to TSI, as has been done previously (Sander et al., 2001). The 10 excluded patients consisted of nine TBI patients and one stroke patient that were between two and 14 years post-injury.

DRS scores. Interrater reliability has been shown to range from .97 to .98 (McCauley, Hannay, & Swank, 2001).

Supervision Rating Scale (SRS). Independent living status was assessed using the SRS (Boake, 1996). The SRS is a one-item instrument, in which the level of supervision a person is *actually* receiving (i.e., not what a person is judged or predicted to need) is rated on a 13-point ordinal scale. Responses range from one ("the patient lives alone or independently") to 13 ("the patient is in physical restraints"). As well, ratings in the 13-point SRS automatically categorize the patient into one of five supervision levels (see Table 3). This instrument has been demonstrated to have adequate reliability and validity in a brain injury sample. SRS ratings have been shown to be strongly associated with ratings on the DRS and Glasgow Outcome Scale. Interrater reliability of the SRS was found to be satisfactory (intraclass correlation = .86, weighted kappa = .64; Boake, 1996).

Craig Handicap Assessment and Reporting Technique – Short Form (CHART-SF). The CHART-SF (Mellick, 2000; Whiteneck et al., 1992) is a measure of social role participation. It was recommended by the CDE TBI Outcome Workgroup as the core measure to be included in TBI research to assess the outcome domain of social role participation (Wilde et al., 2010). The CHART-SF consists of 19 items designed to provide a simple, objective measure of the degree to which impairments and disabilities result in handicaps in the years after initial rehabilitation. It approximates the same six subscale scores from the revised version of the original CHART (Whiteneck et al., 1992), which were created to map onto the dimensions of handicap (now "participation") outlined by the WHO and include: 1) Physical Independence: ability to sustain a customarily effective independent existence; 3) Cognitive Independence: ability to orient oneself to his or her surroundings; 3) Mobility: ability to move about effectively in his or her surroundings; 4) Occupation: ability to occupy time in the manner customary to that person's sex, age, and culture; 5) Social Integration: ability to participate in and maintain customary social relationships; and 6) Economic Self-Sufficiency: ability to sustain customary socio-economic activity and independence (Mellick, 2000). For this study, only the first five subscales were utilized. The CHART-SF has been shown to have high test-retest reliability when administered to numerous disability groups (e.g. TBI, stroke, burn, and amputation) as well as good discrimination across impairment categories (Walker, Mellick, Brooks, & Whiteneck, 2003). The CHART-SF items focus on objectively observable criteria which are less likely to be open to subjective interpretation, and thus, items identify behaviors rather than perceptions or attitudes. The questions are weighted and given scores. The scores within each subscale are summed to yield a total score ranging from zero to 100, with a score of 100 representing the average performance of a typical, non-disabled individual in the respective domain (Mellick, 2000).

Procedure

Demographic information (e.g. age, gender, education level, ethnicity, pre-injury work status, and marital status), injury characteristics (e.g., specific etiology, lesion lateralization, and acute injury severity variables), and pre-morbid health variables (e.g. diagnosis of hypertension, diabetes, coronary artery disease, or hyperlipidemia) were obtained, when available, for each study participant through the individual's PABIR medical records. Admission and discharge assessments were completed via clinician consensus during a bi-monthly transdisciplinary program evaluation meeting. Telephone interviews conducted by trained individuals were used to collect follow-up data at approximately six months post-discharge from Mentis. An interrater reliability study was performed on nine telephone interviews of former program participants. The two raters agreed on 201/225 observations, yielding a percent agreement rate of 89.3%. In addition, ongoing reliability checks were performed on five percent of the sample. Health-related outcome data collected via telephone interview has been shown to be similar to those data collected through means of face-to-face interviews (Korner-Bitensky, Wood-Dauphinee, Siemiatycki, Shapiro, & Becker, 1994). Moreover, telephone follow-up is more practical and inexpensive than face-to-face interviews due to the long distances between participants' homes and the rehabilitation facility and, thus, was the preferred method of follow-up. Follow-up telephone interviews were conducted with the individual deemed by the team as most likely to provide accurate information; therefore, the source was typically a close family member or significant other, and occasionally a nonrelated caregiver or the patient himself. Proxies have been found to provide reliable data via the CHART-SF in both TBI and stroke populations (Cusick, Brooks, & Whiteneck, 2001).

Data Analyses

Data Cleaning

Regular quality control was performed on collected data to ensure collection accuracy. The study database included several embedded validity checks and field limits (i.e., numerical constraints and field constraints) to decrease data entry errors (e.g., gender field did not accept any response other than “male” or “female,” evaluation date could not precede admission date, etc.). Prior to data analyses, data cleaning was conducted as outlined in Tabachnick and Fidell (2006). Data cleaning included format checks, completeness checks, limit checks, and review of the data to identify other errors of the data. Each variable was checked for missing values, invalid values, and outliers. Data entry errors were corrected. One patient with stroke was missing a date of onset; thus, the time since injury was quantified as the mean of the stroke group. Likewise, mean values were imputed for three patients with stroke who were missing data regarding their years of education.

Statistical Procedures

Descriptive Statistical Analyses. All statistical analyses were carried out using IBM SPSS Statistics 17.0 software. Prior to conducting analyses to test specific hypotheses, detailed descriptive analyses were performed. Differences in demographic, clinical, and pre-morbid health characteristics were examined between patients with TBI and stroke. Independent t-tests were used to test for differences in continuous variables (e.g., age, education). Levene’s Test for Equality of Variance was used to detect violations of the homogeneity of variance (HOV) assumption when performing t-tests. In the event that the HOV assumption was violated, the separate-variance t-test statistic was interpreted. Chi-square analyses were used to test for group differences in categorical variables (e.g., gender, race). When necessary, discrete variables were collapsed across categories in a meaningful way to ensure that expected cell counts were sufficient. In the event of a statistically significant chi-square result, standardized cell residuals were examined to make inferences about specific group differences (Field, 2009). Differences between RP and RP+ patients were examined using the same approach. Finally, TBI- and stroke-specific injury characteristics were examined and presented in table format. Frequencies and percentages were presented for nominal characteristics and means and standard deviations were presented for scale and interval characteristics.

Primary Statistical Analyses.

Hypothesis 1. Two split-plot, repeated measures ANCOVAs were conducted using a univariate approach, each with one between-subjects factor (etiology: TBI, stroke) and 1 within-subjects factor (time: admission, discharge, six-month follow-up). The first ANCOVA examined changes in DRS scores over time, while the second examined changes in SRS scores over time. Theoretically appropriate covariates were determined based on previous literature. The covariates included were TSI, length of rehabilitation stay (LOS), and program type (RP versus RP+). Admission level of functioning was accounted for by nature of the repeated measures design, in which each participant serves as their own control. The assumptions of split-plot, repeated measures ANCOVA were evaluated for each analysis (i.e., multicollinearity, normality of residuals, homogeneity of variance, homogeneity of regression slopes, linearity of regression, independence of error terms, and sphericity). Significance level was set at $p < .05$. The main effect of time was examined to test Hypothesis 1a. The interaction effect of etiology*time was examined to test Hypothesis 1b. Significant effects were followed up by post-hoc comparisons (least square differences [LSD] method) to determine between which time points statistically significant change occurred after adjusting for covariates. The Bonferroni correction procedure was applied to post-hoc comparisons in order to control type I error rate. Power and effect size analyses were conducted post-hoc to aide in interpretation of significant findings or lack thereof.

Hypothesis 2. The six-month follow-up CHART-SF subscale distributions were examined by etiology and found to be non-normal due to psychometric properties of the measure (e.g., tendency toward ceiling effect, not all values were equally likely to be represented). Therefore, non-parametric Mann-Whitney U tests were performed to compare the distributions of the five CHART-SF subscale scores at six-month follow-up between TBI and stroke patients. One-tailed exact significance tests were examined. Significance level was set at $p < .05$. Effect size, r, was calculated using the formula $r = Z/\sqrt{N}$. Separate variance t tests were used to test for differences in six-month SRS and DRS outcomes between stroke and TBI patients. Again, significance level was set at $p < .05$.

Hypothesis 3. Hierarchical logistic regression was used to examine the unique relationships of covariates, demographic characteristics, health comorbidities, and etiology with CHART-SF outcomes. Logistic, rather than linear, regression was utilized due to the distribution characteristics of the outcome variables (CHART-SF subscale scores at six-month follow-up). Specifically, examination of the six-month CHART-SF subscale distributions revealed that a disproportionate amount of individuals had the highest possible score of 100. Therefore, CHART-SF subscale variables were re-coded into dichotomized indicator outcome variables. Individuals with a score of 100 were assigned a value of "1" and labeled as having no impairment in that particular CHART-SF domain. Those with scores less than 100 were assigned a value of "0" and labeled as having some level of impairment in that particular domain. Two hierarchical logistic regression models were fit for each dichotomized CHART-SF outcome variable. In the first model, each CHART-SF variable was regressed first on a set of covariates that were selected based on theory and previous literature (block A: TSI, admission DRS score, LOS, program type). Next, etiology (block C) was entered into the model to determine if there was a unique effect of etiology on outcomes after accounting for covariates. In the second model, the CHART-SF outcome variables were again regressed first on the set of covariates (block A). They were then regressed on the demographic and health variables that are theoretically related to etiology (block B: age, years of education, number of health comorbidities). Finally, etiology was entered into the model (block C) to determine if any effects of etiology were still present after age, education, and health comorbidities had been taken into account. Wald statistics were examined to determine which variables were significant predictors of outcome. Significance level was set at $p < .05$. Beta weights and odds ratios (OR) were examined to interpret the nature of the relationship between significant predictors and CHART-SF outcomes.

Analogous hierarchical linear regression models were then used to examine the relationships between the same blocks of predictors and the continuous six-month DRS and SRS outcome variables. The assumptions of linear regression were evaluated for each analysis (i.e., linearity of regression, normality of residuals, homoscedasticity of residuals, independence of residuals, multicollinearity). *B* weights and *t* statistics were examined to determine which variables were significant predictors of outcome. Significance level was set at $p < .05$. Standardized beta weights were examined to interpret the nature of the relationship between significant predictors and DRS and SRS outcomes.

Finally, bivariate and partial correlations were examined and compared in order to determine if the relationships between predictor variables and outcome variables changed after the effect of etiology was partialed out. First, bivariate correlations were computed and examined for significance. Pearson's correlation coefficients were computed when both variables were continuous, point biserial correlation coefficients were computed when one variable was continuous and one was dichotomous, and phi correlation coefficients were computed when both variables were dichotomous. These values were then compared to the partial correlations between predictors and six-month outcome variables after the effect of etiology was removed. If a pair of bivariate and partial correlations between a particular predictor and outcome variable differed significantly, this indicated a need for further exploration of the relationship between etiology, the predictor variable, and outcome.

Results

Sample Descriptives

Detailed demographic characteristics of study participants are presented by etiology and program type in Tables 4 and 5, respectively. On average, TBI patients differed significantly from stroke patients in that they were younger, $t(111.66) = 5.22$, $p < .001$, and less educated, $t(112) = 2.15$, $p = .034$. Chi-square analyses revealed that etiology was significantly related to gender, $\chi^2(1) = 9.71$, $p = .002$, and marital status, $\chi^2(2) = 15.98$, $p < .001$. Examination of standardized cell residuals suggested that patients with TBI were more likely to be male, more likely to be single/never married, and less likely to be divorced/separated/widowed compared to patients with stroke. Regarding premorbid health characteristics, patients with stroke were more likely to have a history of prior stroke or TIA, $\chi^2(1) = 7.04$, $p = .008$[3], hypertension, $\chi^2(1) = 21.31$, $p < .001$, high cholesterol, $\chi^2(1) = 15.09$, $p < .001$, and heart disease, $\chi^2(1) = 5.17$, $p = .023$, relative to patients with TBI. Patients in the RP and RP+ programs were similar across all characteristics, except LOS, which was longer for those who participated in the RP+ program, as to be expected, $t(77.89) = 6.51$, $p < .001$. Detailed injury characteristics of patients with TBI and stroke are presented in Tables 6, 7, and 8.

Hypotheses 1

DRS ANCOVA. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 14.68$, $p = .001$; therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .89$). TSI, LOS, and program type were included as covariates. The homogeneity of regression slopes assumption was met for all covariates. There was a significant main effect of time on DRS scores, $F(1.77, 191.46) = 49.89$, $p < .001$, *partial* $\eta^2 = .32$. Post-hoc LSD pairwise comparisons conducted on the adjusted means scores using a Bonferroni correction procedure (p =.05/3) revealed that DRS scores decreased significantly (indicating less disability) from admission to discharge, $p < .001$, and from discharge to six-month follow-up, $p =.004$. There was no significant interaction effect between time and etiology, indicating that the effect of time on DRS scores was generally the same for patients with TBI and stroke, $F(1.77, 191.46) = 1.17$, $p = .309$. The only covariate that interacted significantly with time was TSI, $F(1.77, 191.46) = 13.25$, $p < .001$. Post-hoc analyses revealed that individuals who were further post-injury tended to make smaller gains from admission to discharge, but that TSI was not related to gains made from discharge to six-month follow-up. Table 9 displays the adjusted mean estimates of DRS scores across each time point by etiology and Figure 1 depicts these estimates graphically. Table 10 displays results of the full DRS ANCOVA model.

[3] Greater than 20% of expected cell counts were less than five for this analysis; therefore, results should be interpreted with caution.

SRS ANCOVA. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 9.18$, $p = .01$; therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .92$). TSI, LOS, and program type were included as covariates. The homogeneity of regression slopes assumption was met for all covariates. There was a significant main effect of time on SRS scores, $F(1.85, 199.59) = 68.23$, $p < .001$, *partial* $\eta^2 = .39$. Post-hoc LSD pairwise comparisons conducted on the adjusted means scores using a Bonferroni correction procedure (p =.05/3) revealed that SRS scores decreased significantly (indicating less disability) from admission to discharge, $p < .001$, and from discharge to six-month follow-up, $p = .002$.There was no significant interaction effect between time and etiology, indicating that the effect of time on SRS scores was generally the same for patients with TBI and stroke, $F(1.85, 199.59) = 0.79$, $p = .446$, *partial* $\eta^2 = .01$. There were two covariates that interacted significantly with time: TSI, $F(1.85, 199.59) = 48.70$, $p < .001$, and program type $F(1.85, 199.59) = 4.28$, $p = .007$. As was found in the DRS ANCOVA, post-hoc analyses showed that individuals who were further post-injury tended to make smaller gains in SRS scores from admission to discharge, but that TSI was not related to gains made from discharge to six-month follow-up. Post-hoc follow-up of the time by program type interaction showed that patients in the RP+ program made greater gains in SRS scores from admission to discharge and maintained these gains at six-month follow-up, while patients in the RP program made fewer gains from admission to discharge, but then continued making gains from discharge to six-month follow up, such that there was no significant difference in SRS scores at six-month follow-up (Figure 2). Table 7 displays the adjusted mean estimates of SRS scores across each time point by etiology and Figure 3 depicts these estimates graphically. Table 11 displays results of the full SRS ANCOVA model.

Hypothesis 2

Results from five separate Mann-Whitney U tests revealed that TBI patients were higher in Physical Independence, $U = 1186.00$, $p = .004$, $r = .26$, and Mobility, $U = 1179.00$, $p = .022$, $r = .19$, at six-month follow-up relative to stroke patients. TBI patients did not differ significantly from stroke patients in Cognitive Independence, Occupational, or Social Integration scores at six-month follow-up.

Complete Mann-Whitney U test results are presented in Table 12. Results from separate variance *t* tests showed that six-month SRS and DRS scores did not differ significantly between stroke and TBI patients.

Hypothesis 3

Hierarchical logistic regression results revealed that, after controlling for covariates, etiology was a significant predictor of Physical Independence at six-month follow-up, $W = 11.78$, $p = .001$, in that TBI patients were approximately nine times more likely than stroke patients to be physically independent at six-month follow-up. This relationship remained significant after age, education, and number of health comorbidities were accounted for, $W = 9.67$, $p = .002$. Etiology was not significantly related to any other CHART-SF outcome variable, before or after accounting for demographic and health variables. Age was a significant predictor of Physical Independence, Cognitive Independence, and Mobility at six-month follow-up (older age was related to being impaired), but age was not related to Occupational or Social Integration outcomes. Education and number of health comorbidities did not predict CHART-SF outcomes. Detailed hierarchical logistic regression results are presented in Table 13.

Hierarchical linear regression results revealed that, after controlling for covariates, etiology was related to six-month SRS outcome, in that stroke patients tended to receive more supervision than TBI patients, $b = .824$, $t(108) = 2.02$, $p = .046$. However, this relationship dissipated after age, education, and number of health comorbidities were included in the model. Etiology was not related to DRS outcome, before or after accounting for demographic and health variables. Age was a significant predictor of both DRS and SRS scores, in that those who were older tended to have higher DRS scores (i.e., more disability), $b = .039$, $t(105) = 2.92$, $p = .004$, and higher SRS scores (i.e., receive more supervision), $b = .049$, $t(105) = 3.51$, $p = .001$. Education and number of health comorbidities were not related to DRS or SRS outcomes. Detailed hierarchical linear regression results are presented in Table 14.

The bivariate correlation matrix between predictor variables and six-month outcome variables is presented in Table 15. The partial correlation matrix between predictor variable and six-month outcome variables after removing the effect of etiology is presented in Table 16. There were no significant differences between bivariate and partial correlations for any given pair of predictor and outcome variables. This suggests that the observed relationships between predictors and outcomes seen in the above regression analyses are not moderated by etiology.

Discussion

PABIR is a broad umbrella term that refers to specialized rehabilitation programs for individuals with ABI who are able to benefit from further intervention beyond acute/subacute rehabilitation (Malec & Basford, 1996). Though PABIR programs can take many shapes and forms, they are distinguished from other post-acute interventions in that they aim to holistically address multiple aspects of dysfunction through the implementation of individualized treatment plans by a transdisciplinary team. Thus far, the large majority of PABIR research studies have examined the effectiveness of these programs in samples comprised largely or solely of TBI patients. Systematic reviews of this literature have yielded conflicting conclusions. While a number of reviews concluded that PABIR for patients with moderate-to-severe TBI resulted in reduced disability and improved social integration and community participation (Cicerone et al., 2000; Cicerone, 2004; Cicerone, Azulay, & Trott , 2009; Cicerone et al., 2005; Cicerone et al., 2011; Malec & Basford, 1996; Turner-Stokes et al., 2011), two recent reviews, that relied heavily on RCTs, reported inconclusive findings to date (Brasure et al., 2012; Institute of Medicine, 2011). Individuals with non-traumatic ABI are also treated in PABIR programs – in particular, individuals who have suffered a stroke. Less is known about PABIR effectiveness for individuals with stroke and other acquired neurological conditions. The current study was the first, to our knowledge, to compare outcomes of TBI and stroke patients who participated in an explicitly defined, comprehensive-holistic, residential PABIR program. The aims of this study were to (1) describe the characteristics of TBI and stroke patients presenting to the PABIR level of care, (2) compare the effectiveness of PABIR for patients with TBI versus stroke, and (3) examine those factors which predicted successful outcome from PABIR in these patients.

Aim 1

In the current study, detailed injury characteristics of our TBI and stroke samples were presented in an effort to better understand the nature of the injuries suffered by individuals likely to present for

PABIR. Because of the heterogeneous nature of ABIs suffered by patients who present for PABIR, knowledge about detailed injury characteristics becomes important when interpreting results from studies and making statements about generalizability of findings. The vast majority of TBI patients in our sample suffered closed head injuries (95.8%), with motor vehicle accident (MVA) being the most common mechanism of injury (52.8%) followed by falls (25.0%). Recent data shows that, within the general population, falls are the most common cause of TBI (35.2%) followed by MVA (17.3%; Faul, Likang, Marlena, & Victor, 2010); therefore, it appears that TBIs caused by MVA are overly represented in our sample, which may speak to the severity of injury caused by MVA (see Table 7). While GCS scores were missing in almost a third of our TBI sample, of those who did have GCS scores, 71.4% had scores consistent with a severe TBI. Given previous reports that fewer than 10% of all TBIs are classified as severe (Cohadon et al., 2000; Lezak, 1989), this data suggests that individuals with severe TBI are overly represented at the PABIR level of care. This is not surprising, as those with severe injuries are more likely to require more intensive rehabilitation above and beyond that provided in acute care and acute rehabilitation hospitals.

Among those who suffered strokes, approximately half were ischemic in nature, while the other half were either hemorrhagic or a combination of ischemic and hemorrhagic. Research suggests that less than 20% of all strokes are hemorrhagic (Bogousslavsky, Hommel, & Bassetti, 1998); therefore, like severe TBI, this suggests that hemorrhagic stroke is over-represented at the PABIR level of care. Again, this is likely due to hemorrhagic stroke being associated with greater initial stroke severity, higher mortality, and poorer long-term neurologic outcomes compared to ischemic stroke (Barber, Roditi, Stott, Langhorne, 2004; Gebel & Broderick, 2000; Nadeau et al., 2006), so these individuals are more likely to require more intensive rehabilitation. Our data showed that stroke patients were equally likely to have infarcts that lateralized to the left, right, or both hemispheres, suggesting that there is not a particular lateralization pattern that is more likely to require PABIR. Hemiparesis was diagnosed in approximately70% of stroke patients, suggesting that those with physical sequelae of stroke are likely to present for PABIR.

In addition to examining stroke- and TBI-specific injury characteristics, more general demographic and clinical characteristics were compared across TBI and stroke groups. Accounting for differences in demographic and clinical characteristics across etiologic groups is imperative when making comparisons between them. Consistent with what would be expected based on previous literature, TBI and stroke patients differed on several characteristics thought to be relevant to predicting outcome following neurological insult. Specifically, TBI patients were younger and less likely to be diagnosed with premorbid health conditions (i.e., prior stroke or TIA, hypertension, high cholesterol, and heart disease). These characteristics should predispose them to better long-term outcome from ABI (Adams et al., 2004; Cohadon et al., 2002; Klonoff et al., 2006; Rothweiler, Temkin, & Dikmen, 1998). However, patients with stroke were more highly educated and more likely to be married, which some research suggests may increase their likelihood of a good outcome (Klonoff et al., 2006; Mushkudiani et al., 2007).

Patients with TBI and stroke did not differ on other demographic and clinical variables, including race, pre-injury employment status, type of setting from which they admitted, level of functioning at admission (i.e., admission DRS scores), or length of stay in PABIR. As well, patients with TBI and stroke were equally likely to participate in the RP versus the RP+ program, a decision that is made collaboratively by the treatment team, patient, and family members who are often influenced by multiple factors (e.g., treatment needs/present goals, proximity of the patient's home to the PABIR facility, insurance considerations, etc.). Finally, the TBI and stroke patients included in the current study did not differ in length of TSI upon admission to PABIR. However, it should be noted that individuals who were greater than two years post injury were excluded from the current study because these individuals were felt to represent a unique population of PABIR clientele (e.g., individuals who were referred for PABIR many years post-injury because they continued to have significant cognitive, behavioral, and psychosocial difficulties at home). Of the 10 patients excluded due to this criterion, nine were TBI patients, suggesting that TBI patients may be more likely than stroke patients to present for PABIR after several years post-injury. A possible reason for this may be the younger age of injury onset common in TBI, which can result in significant cognitive and interpersonal impairments in young individuals with long lives ahead of them. It is these individuals and/or their families that may be likely to seek treatment many years after injury onset, and in turn, find themselves referred for PABIR services.

To summarize, the current study sample was comprised of TBI and stroke patients who admitted to PABIR within 2 years of injury onset. Based on available injury information, it appears that more severe injuries are over-represented in both groups relative to population incidence statistics. Etiology groups differed on several characteristics that may be related to outcome, including age, education, marital status, and number of premorbid health conditions. Groups were similar across a number of other characteristics including race, pre-injury employment status, admission level of functioning, TSI, and LOS.

Aim 2

Findings from the current study revealed that individuals experienced significant improvement in disability and independence level over the course of PABIR participation. These findings are consistent with those reported previously in the literature (Cicerone et al., 2000; Cicerone, 2004; Cicerone, Azulay, & Trott , 2009; Cicerone et al., 2005; Cicerone et al., 2011; Malec & Basford, 1996; Turner-Stokes et al., 2011). After adjusting for TSI and LOS, the patients in this study showed, on average, a 3-point reduction in DRS scores from admission to discharge, which represented a significant decrease in overall disability for these individuals. Likewise, they demonstrated an almost 4-point reduction in SRS scores, indicating that, on average, these individuals required significantly less supervision at discharge relative to admission. In addition to being statistically significant, these findings represented clinically meaningful change that likely had important implications for the patient and his or her family members/caregivers. As an example, a four-point change in SRS scores could represent the difference between an individual requiring full-time, indirect supervision 24 hours per day (SRS = 8) to being left alone during working hours and allowed on independent outings (SRS = 4). Certainly, this notable decrease in supervision need is likely to provide the individual with a greater sense of independence, which may foster further recovery in other domains. As well, this amount of change is likely to reduce the emotional and financial burden suffered by the family members caring for individuals with ABI.

For obvious reasons, previous literature has placed a large emphasis on the extent to which rehabilitation gains are maintained following discharge from rehabilitation. In the current study sample, improvements made during PABIR were not only maintained at six-month follow-up, but, on average, patients continued to make significant, albeit smaller, improvements in disability and supervision status from discharge to six-month follow-up. This finding provides evidence that the gains observed over the course of rehabilitation generalized to the individual's home community settings and were maintained over time, which is the ultimate goal of PABIR.

Taken together, these findings provide support for Hypothesis 1a, which predicted that both patients with TBI and stroke would make functional gains over the course of PABIR. It was also hypothesized that, while all patients would have lessened disability and decreased need for supervision, patients with stroke would demonstrate a slower rate of functional change, resulting in less cumulative gains over time relative to TBI patients (Hypothesis 1b). It follows that stroke patients would have greater disability and require more supervision relative to TBI patients at six-month follow-up (Hypothesis 2). Results from this study showed that stroke and TBI patients entered the program with similar levels of disability and supervision needs, made comparable gains over the course of rehabilitation, and maintained gains following discharge, ultimately resulting in similar levels of disability and supervision level at six-month follow-up. However, after controlling for the effects of relevant covariates (e.g., TSI, admission DRS scores, program type, and LOS), etiology did emerge as a significant predictor of supervision level at six-month follow-up. That is, stroke etiology was associated with a 0.82 increase in SRS score (i.e., more supervision received). A similar relationship was noted between etiology and six-month DRS scores, with stroke etiology being related to a 0.70 increase in DRS score (i.e., more disability), but this relationship did not reach significance ($p = .071$). After etiology-related variables (i.e., age, education, and number of comorbid health conditions) were included in the model, etiology was no longer related to DRS and SRS outcomes; instead, age emerged as the sole significant predictor above and beyond covariates. This suggests that etiology was simply serving as a proxy for age in predicting SRS and DRS outcomes at six-month follow-up.

The goal of PABIR is broader than decreasing both disability and the need for supervision. In PABIR, there is a large emphasis on improving the individual's overall quality of life by facilitating re-integration into home and societal roles. The CHART-SF measures social role participation outcomes (i.e., re-integration) across multiple domains. It was hypothesized that TBI patients would have better participation outcomes relative to stroke patients at six-month follow-up (Hypothesis 2). Consistent with this hypothesis, the CHART-SF scores of stroke patients were lower on average across all domains relative to TBI patients; yet, these differences only reached statistical significance in those domains highly dependent on physical functioning – namely, the Physical Independence and Mobility subscales.

The CHART-SF Physical Independence subscale is comprised of only one item that measures the number of hours per day the individual requires hands-on physical assistance. Our data indicated that stroke patients required more hands-on physical assistance at six-month follow-up relative to TBI patients. After controlling for the effects of relevant covariates (e.g., TSI, admission DRS scores, program type, and LOS), etiology remained a significant predictor of Physical Independence at six-month follow-up, in that TBI patients were approximately 9 times more likely than stroke patients to be physically independent (i.e., require no hands-on physical assistance) at six-month follow-up. This effect remained after etiology-related variables (i.e., age, education, and number of comorbid health conditions) were included in the model (of these variables, only age emerged as a significant predictor of Physical Independence). This finding indicates something unique about stroke patients, aside from older age, that makes them less likely to be physically independent following PABIR. One possible explanation is the high percentage of hemiparesis (70%) seen in our stroke sample.

The CHART-SF Mobility subscale is a composite score comprised of three items measuring the number of hours spent out of bed per day, number of days per week the individual leaves his or her home, and number of nights spent away from home in the last year (or since the injury, if less than one year's time has passed). Results suggested that stroke patients were, on average, more likely to be impaired in the Mobility domain relative to TBI patients. However, after controlling for relevant covariates and etiology-related variables, etiology did not predict who was more likely to be impaired on the Mobility subscale, as only age emerged as a significant predictor. This finding indicates that age, rather than etiology, is important in predicting mobility outcomes at six-month follow-up. Nonetheless, it seems stroke patients are vulnerable to poorer Mobility outcomes because of their average older age.

In summary, both patients with TBI and stroke benefited from participation in PABIR, as evidenced by significant gains made in both disability and supervision level over the course of rehabilitation that were well-maintained at six-month follow-up. After controlling for relevant covariates, stroke etiology was related to poorer SRS, DRS, and Mobility outcomes at six-month follow-up, but these relationships dissipated once age was included in the model. However, etiology was found to uniquely predict likelihood of physical independence above and beyond relevant covariates and age.

Aim 3

To date, relatively few researchers have investigated relevant demographic and premorbid characteristics that may predict an individual's response to PABIR (Klonoff et al., 2006). Though the relationships of demographic variables and outcome following ABI in general have been studied widely, much less is known about how these factors are related to outcome at the PABIR level of care. The current study used hierarchical logistic and linear regression modeling to examine those variables which predicted disability, supervision needs, and participation outcomes at six-months following discharge from PABIR. It was hypothesized that younger age, higher education, and fewer comorbid health conditions would be related to positive outcomes from PABIR for both patients with TBI and stroke (Hypothesis 3).

As discussed in the previous section, etiology was related to supervision level, disability (non-significant trend; $p=.071$), physical independence, and mobility at six-month follow-up, in that stroke patients tended to have poorer outcomes in these domains. With one exception, the effect of etiology dissipated when age was included in the models, this exception being that stroke etiology continued to uniquely predict impaired physical independence outcomes at six-month follow-up above and beyond relevant covariates and age. Taken together, these findings suggest that, with the exception of physical independence, disparities in outcome by etiology are being driven by differences in age, rather than etiology itself.

Older age was also related to a handicap in Cognitive Independence at six-month follow-up. The CHART-SF Cognitive Independence subscale is comprised of two items which measure the amount of supervision the individual requires inside and outside of the home specifically because of problems with "remembering, decision making, and judgment." A possible explanation for the relationship between age and cognitive independence is that younger individuals are more likely to have pre-morbidly healthier brains that are more resilient to the cognitive effects of acquired injury (consistent with the theory of cognitive reserve).

Of note, age was not related to productivity or social integration outcomes, as measured by the CHART-SF Occupational and Social Integration subscales. The Occupational subscale is comprised of five items that seek to document the amount of hours per week the individual spends engaging in productive activities which include, but are not limited to, working, studying, homemaking, parenting, housekeeping, food preparation, home maintenance, gardening, house repairs, home improvement, sports, exercise, and other recreational, social, and leisure activities. The Social Integration subscale is comprised of five items that inquire about the person's social living environment (e.g. number of individuals he or she lives with, the relationship he or she has with these individuals), the number of business/organizational associates and friends with whom the person keeps in regular contact, and the frequency with which the person initiates conversation with strangers. Thus, while age was found to be consistently related to multiple domains of outcome, it does not appear that good outcomes in productivity and social integration hinge upon the individual's age. Also, education and number of comorbid health conditions were not related to six-month PABIR outcomes in any domain. Thus, our data provided partial support for Hypothesis 3 in that age was related to most, but not all, outcome domains, but education and number of comorbid health problems were unrelated to outcome.

TSI, admission DRS scores, program type, and LOS were the four covariates included in the first step of each regression model. Though they were not the main predictor variables of interest, a discussion of their relationships with outcome seems warranted. Of these covariates, TSI and admission DRS scores were most frequently predictive of six-month PABIR outcomes, followed by LOS, which was only related to outcome in a few domains. Of note, program type was not related to six-month outcomes in any domain. This suggests that individuals were not more or less likely to experience positive outcomes depending on the program in which they participated (i.e., RP versus RP+). These data provides support for the notion that one program model is not necessarily superior to another for all individuals, but rather the importance lies in matching the individual to the program type that best fits his or her rehabilitation needs.

TSI was related to both disability and supervision levels at six-month follow-up, as those who were earlier in their recovery at the time of admission to PABIR tended to have better outcomes at six-month follow-up. These results go hand-in-hand with the finding that individuals who were earlier post-injury tended to make greater SRS and DRS gains from admission to discharge. Likewise, those who were earlier in their recovery were less likely to be impaired in Physical Independence, Cognitive Independence, and Social Integration at six-month follow-up. All together, these findings are consistent with previous research showing that those individuals earlier in their recovery are more likely to make greater rehabilitation gains by capitalizing on spontaneous recovery (Benge et al., 2010; Cope et al., 1991a; High et al., 2006; Malec et al., 1993; Wood et al.,1999). In addition, it is possible that those who presented for PABIR earlier post-injury may have suffered comparatively less severe injuries and/or were recovering more favorably, as evidenced by their faster progress through acute stabilization and acute rehabilitation relative to those who took longer to present for PABIR. Importantly, TSI was not related to Mobility or Occupational (i.e. productivity) CHART-SF outcomes, suggesting that these outcome domains are less related to the effects of spontaneous recovery.

Admission level of functioning, as captured by the individual's admission DRS scores, was predictive of six-month DRS, SRS, Physical Independence, and Cognitive Independence outcomes. As would be expected, those with higher level of functioning at admission were more likely to have better outcomes in these domains at six-month follow-up. Worth noting, however, is the finding that admission level of functioning did not predict Mobility, Occupational, or Social Integration outcomes. This finding implies that individuals can and do achieve successful outcomes in these domains regardless of overall level of disability upon admission through participation in PABIR.

Those individuals with a longer LOS were more likely to have poorer DRS, SRS, and Physical Independence outcomes at six-month follow-up. An obvious explanation for this finding is that individuals with more significant cognitive, behavioral, and physical impairments, who were susceptible to poorer outcomes, may have required a longer length of stay due to greater rehabilitation needs. LOS, however, was not related to Cognitive Independence, Mobility, Occupational, or Social Integration outcomes.

Finally, it is important to mention that data from the current study did not suggest that the variables studied differentially predicted outcome for patients with TBI versus stroke. In other words, all predictive relationships (or lack thereof) were similar in magnitude for both stroke and TBI patients.

To summarize, after accounting for covariates and demographic variables, etiology was uniquely related only to Physical Independence outcomes at six-month follow-up, with stroke patients being much less likely to achieve physical independence. Of the etiology-related characteristics studied, only age was predictive of outcome in all domains except CHART-SF Occupational and Social Integration subscales. Education and number of comorbid health conditions were not related to six-month outcomes. TSI was related to outcomes in multiple domains in that those who were earlier post-injury tended to have better outcomes. Additionally, those who were at a higher level of functioning upon admission to PABIR also had higher outcomes across multiple domains. However, there were some outcome domains that were less related to covariates and other predictor variables – namely, the CHART-SF Occupational and Social Integration subscales. Thus, it appears that other factors not measured and studied in the current work are related to productivity and social outcomes from ABI.

Strengths, Limitations, and Future Directions

The current study contributed to the existing literature in that it examined, in depth, the characteristics of stroke and TBI patients who participated in a comprehensive, multidisciplinary residential PABIR program, which is a first to our knowledge. It also compared the outcomes of stroke and TBI patients who participated in the same program, which has not yet been investigated in an explicitly stated PABIR program to our knowledge. Finally, this study examined the relationship between a number of clinical and demographic variables and multiple domains of outcome following PABIR.

Special care was taken in the current study to account for the commonly cited methodological caveats that arise in PABIR research. The heterogeneity of the patient population was addressed using descriptive, methodological, and statistical techniques. As mentioned, the injury, demographic, and clinical characteristics of our sample were described in much greater detail than what has been typically presented in previous articles. Moreover, we chose to include only patients with ABI secondary to trauma (i.e., TBI) or cerebral vascular accident (i.e., stroke), which are the two most common forms of ABI (CDC, 2008; Faul et al., 2010), in an effort to study these two etiologies in a purer fashion. This is in contrast to previous studies that have compared patient with traumatic and non-traumatic injuries, with the latter group including a number of different etiologies with potentially different outcome courses. As well, we limited our sample to include only those who were within two years of injury onset, so as to isolate a more homogenous sample with regards to TSI. Lastly, after taking methodological steps to reduce heterogeneity, we also statistically accounted for relevant variables in conducting our analyses, including TSI, admission level of functioning, LOS, age, education, and number of comorbid health problems.

Another strength of the current study was the number, variety, and quality of outcome measures utilized. The outcome measures/scales chosen for this study have been demonstrated to have good reliability and validity in samples of individuals with brain injury (Boake, 1996; McCauley, Hannay, & Swank, 2001; Rappaport et al., 1982; Whiteneck, Fougeyrolles, & Gerhart, 1997). Also, the chosen measures covered a range of outcomes relevant to ABI including overall level of disability (i.e., DRS), supervision needs (i.e., SRS), and social role participation across five different domains (i.e., CHART-SF). This afforded us the opportunity to examine differential relationships between predictor variables and certain aspects of outcome. For example, it appears as though productivity and social outcomes are not highly related to any of the predictors variables included in our models. Given the importance of these outcome domains, future research should aim to identify other factors not accounted for in this study that predict successful productivity outcome.

A drawback of outcome measurement in the current study was that follow-up data were collected only at six-months post-discharge. While this time frame is sufficient enough to infer maintenance of gains, it would be beneficial to gather data on longer term outcomes (e.g., at 1, 2, or 5 years post-discharge), as some of our patients were still demonstrating improvements at six-month follow-up. We currently have no way to determine whether these improvements continued after six-month follow-up.

A primary limitation of the current study was the lack of a no-treatment comparison group. Lack of a comparison group makes it impossible to fully dissociate the effect of treatment from spontaneous recovery (Sander et al., 2001). Unfortunately, there are significant obstacles to obtaining an appropriate no-treatment control to which valid comparisons could be made from our PABIR sample. Therefore, future research should focus on developing RCTs examining the effectiveness of new treatment elements compared to the standard of care.

An additional shortcoming of the current study is the limited sample sizes of TBI and stroke groups, as well as the inequality between groups. While the group sample sizes were large enough to ensure stability of estimates, it is possible that the samples were not large enough to afford the power necessary for detecting small effects. In an effort to be transparent about these issues, estimates of effect size and observed power were provided for the main analyses. Future research should aim to replicate the current findings in larger samples in order to clarify and expand upon the results of this study.

As is common in PABIR research, initial injury severity indicators were not available for a large portion of our sample, and thus were not included in our statistical models. It should be emphasized that the current study examined change over time while participating in a PABIR program, which represents a relatively small proportion of an individual's overall recovery process. Although initial injury severity has important implications for overall outcome (Richardson, 2000), it was not the goal of this study to examine the course of recovery as a whole, but rather changes made specifically over the course of PABIR treatment.

Conclusions

Overall, this study represents one of the first outcomes studies in which two distinct etiology groups within one explicitly stated PABIR program were examined. This observational study provides evidence that both patients with TBI and stroke experienced improvements in disability and independence level over the course of PABIR participation. It confirms that while stroke patients may be susceptible to slightly poorer outcomes in several domains relative to TBI patients, these differences are largely related to difference in age between the two groups. In addition to age, other variables that were related to outcome included TSI, admission level of functioning, and LOS. However, results revealed that several aspects of participation outcome, including productivity and social integration, were only weakly related to the predictor variables included in this study. This brings to light the need for further research into those factors related to optimal productivity and social outcomes, as these outcome domains are a main focus of PABIR and are thought to be very important in contributing to the individual’s overall quality of life.

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Table 1. Breakdown of sample size by etiology and program type.

Program Type	TBI	CVA
RP	N=40	N=27
RP+	N=32	N=15

Table 2. Interpretation of scores on the DRS.

DRS score	Level of Disability
0	None
1	Mild
2 to 3	Partial
4 to 6	Moderate
7 to 11	Moderately Severe
12 to 16	Severe
17 to 21	Extremely Severe
22 to 24	Vegetative State
25 to 29	Extremely Vegetative State
30	Death

Table 3. Interpretation of scores on the SRS.

SRS score	Level of Supervision
1 to 2	Independent
3	Overnight Supervision
4 to 7	Part-time Supervision
8 to 9	Full-time Indirect Supervision
10 to 13	Full-time Direct Supervision

Table 4. Descriptive statistics by etiology.

Variable	TBI (N=72)	CVA (N=42)
Demographic		
Age, yrs, m (sd)***	41.24 (16.08)	53.93 (9.87)
Education, yrs, m (sd)*	12.92 (2.89)	14.05 (2.39)
Gender**		
Male, n (%)	59 (81.9)	23 (54.8)
Female, n (%)	13 (18.1)	19 (45.2)
Race		
Caucasian, n (%)	35 (48.6)	17 (40.5)
African American, n (%)	19 (26.4)	17 (40.5)
Hispanic, n (%)	15 (20.8)	8 (19.0)
Asian and others, n (%)	3 (4.2)	0 (0.0)
Marital Status***		
Never married/single, n (%)	22 (30.6)	4 (9.5)
Married/partnered/cohabitating, n (%)	43 (59.7)	22 (52.4)
Divorced/separated, n (%)	6 (8.3)	14 (33.3)
Widowed, n (%)	1 (1.4)	2 (4.8)
Pre-injury Employment		
Working, full-time, n (%)	51 (70.8)	33 (78.6)
Working, part-time, n (%)	3 (4.2)	1 (2.4)
Working, sporadically, n (%)	1 (1.4)	1 (2.4)
Homemaker, n (%)	1 (1.4)	1 (2.4)
Student, full-time, n (%)	6 (8.3)	0 (0.0)
Student, part-time, n (%)	2 (2.8)	0 (0.0)
Retired, n (%)	4 (5.6)	6 (14.3)
Unemployed, n (%)	4 (5.6)	0 (0.0)
Clinical		
Admitted From		
Acute care hospital, n (%)	9 (12.5)	5 (11.9)
Rehabilitation hospital, n (%)	36 (50.0)	29 (69.0)
Family or own home, n (%)	26 (36.1)	8 (19.0)
PABIR facility, n (%)	1 (1.4)	0 (0.0)
Program participation		
RP, n (%)	40 (55.6)	27 (64.3)
RP+, n (%)	32 (44.4)	15 (35.7)
Length of stay, days, m (sd)	119.17 (67.41)	107.93 (63.05)
Time since injury, days, m (sd)	169.43 (181.63)	122.71 (147.98)
Admission DRS, m (sd)	7.74 (2.95)	7.71 (2.26)
Pre-Morbid Health		
History of stroke or TIA, n (%)**†	2 (2.8)	7 (16.7)
History of head trauma, n (%)†	3 (4.2)	0 (0.0)
History of hypertension, n (%)***	21 (29.2)	31 (73.8)
History of diabetes mellitus, n (%)†	5 (6.9)	8 (19.0)
History of high cholesterol, n (%)***	6 (8.3)	16 (38.1)
History of heart disease, n (%)*	5 (6.9)	10 (23.8)

Notes: T-tests and chi-square tests were performed to test for group differences in continous and categorical variables, respectively. *significant group difference at p<.05. **significant group difference at p<.01. ***significant group difference at p<.001. † >20% of expected cell counts were less than 5, chi-sqaure results should be interpreted with caution.

Table 5. Descriptive statistics by program participation.

Variable	RP (N=67)	RP+ (N=47)
Demographic		
Age, yrs, m (sd)	46.82 (16.30)	44.62 (13.95)
Education, yrs, m (sd)	13.33 (2.83)	13.34 (2.70)
Gender		
Male, n (%)	48 (71.6)	34 (72.3)
Female, n (%)	19 (28.4)	13 (27.7)
Race		
Caucasian, n (%)	31 (46.3)	21 (44.7)
African American, n (%)	17 (25.4)	19 (40.4)
Hispanic, n (%)	17 (25.4)	6 (12.8)
Asian and others, n (%)	2 (3.0)	1 (2.1)
Marital Status		
Never married/single, n (%)	19 (28.4)	7 (14.9)
Married/partnered/cohabitating, n (%)	32 (47.8)	33 (70.2)
Divorced/separated, n (%)	14 (20.9)	6 (12.8)
Widowed, n (%)	2 (3.0)	1 (2.1)
Pre-injury Employment		
Working, full-time, n (%)	48 (71.6)	36 (76.6)
Working, part-time, n (%)	3 (4.5)	1 (2.1)
Working, sporadically, n (%)	2 (3.0)	0 (0.0)
Homemaker, n (%)	1 (1.5)	1 (2.1)
Student, full-time, n (%)	4 (6.0)	2 (4.3)
Student, part-time, n (%)	2 (3.0)	0 (0.0)
Retired, n (%)	5 (7.5)	5 (10.6)
Unemployed, n (%)	2 (3.0)	2 (4.3)
Clinical		
Etiology		
TBI, n (%)	40 (59.7)	32 (68.1)
CVA, n (%)	27 (40.3)	15 (31.9)
Admitted From		
Acute care hospital, n (%)	7 (10.4)	7 (14.9)
Rehabilitation hospital, n (%)	37 (55.2)	28 (59.6)
Family or own home, n (%)	23 (34.3)	11 (23.4)
PABIR facility, n (%)	0 (0.0)	1 (2.1)
Length of stay, days, m (sd)***	85.09 (46.90)	157.70 (65.63)
Time since injury, days, m (sd)	170.92 (184.13)	125.55 (147.70)
Admission DRS, m (sd)	7.88 (3.02)	7.51 (2.18)
Pre-Morbid Health		
History of stroke or TIA, n (%)†	5 (7.5)	4 (8.5)
History of head trauma, n (%)†	2 (3.0)	1 (2.1)
History of hypertension, n (%)	31 (46.3)	21 (44.7)
History of diabetes mellitus, n (%)	9 (13.4)	5 (10.6)
History of high cholesterol, n (%)	14 (20.9)	8 (17.0)
History of heart disease, n (%)	9 (13.4)	6 (12.8)

Notes: T-tests and chi-square tests were performed to test group differences in continous and categorical variables, respectively. *significant group difference at p<.05. **significant group difference at p<.01. ***significant group difference at p<.001. † >20% of expected cell counts were less than 5, chi-sqaure results should be interpreted with caution.

Table 6. TBI characteristics.

Characteristic	Patients with TBI (N=72)
Type of TBI	
Closed head injury, n (%)	69 (95.8)
Penetrating head injury, n (%)	3 (4.2)
Mechanism of Injury	
Motor vehicle accident, n (%)	38 (52.8)
Fall, n (%)	18 (25.0)
Assault/blunt trauma, n (%)	7 (9.7)
Auto versus pedestrian, n (%)	5 (6.9)
Gun shot wound, n (%)	3 (4.2)
Blast, n (%)	1 (1.4)
GCS Scoring Location	
At the scene, n (%)	21 (29.2)
In the ER, n (%)	20 (27.8)
Location unknown, n (%)	8 (11.1)
GCS information unknown, n (%)	23 (31.9)
GCS Scores	
Mean (sd)	7.33 (3.91)
Mild, 13-15, n (%)	7 (14.3)
Moderate, 9-12, n (%)	7 (14.3)
Severe, 3-8, n (%)	35 (71.4)

Table 7. GCS scores by scoring location and mechanism of injury.

GCS	Scoring Location			Mechanism of Injury		
Scores	**Scene (N=21)**	**ER (N=20)**	**Unknown (N=8)**	**MVA (N=30)**	**Fall (N=10)**	**Other (N=9)**
Mean (sd)	7.43 (3.63)	6.15 (3.41)	10.00 (4.84)	5.90 (3.13)	11.00 (3.16)	8.00 (4.44)
Mild, 13-15, n (%)	3 (14.3)	1 (5.0)	3 (37.5)	2 (6.7)	4 (40.0)	0 (0.0)
Moderate, 9-12, n (%)	2 (9.5)	3 (15.0)	2 (25.0)	1 (3.3)	2 (20.0)	4 (44.4)
Severe, 3-8, n (%)	16 (76.2)	16 (80.0)	3 (37.5)	27 (90.0)	4 (40.0)	5 (55.6)

Table 8. Stroke characteristics.

Characteristic	Patients with CVA (N=42)
Type of Stroke	
Ischemic, n (%)	22 (52.4)
Hemorrhagic, n (%)	18 (42.9)
Both, n (%)	2 (4.8)
Lateralization	
Left, n (%)	15 (35.7)
Right, n (%)	14 (33.3)
Bilateral, n (%)	13 (31.0)
Hemiparesis	
Left, n (%)	13 (31.0)
Right, n (%)	17 (40.5)
None, n (%)	12 (28.6)

Table 9. Adjusted mean estimates and standard errors of DRS and SRS scores at admission, discharge, and six-month follow-up by etiology.

	DRS			SRS		
	Admission	**Discharge**	**6-month FU**	**Admission**	**Discharge**	**6-month FU**
TBI	7.58 (.307)	4.02 (.280)	3.38 (.268)	8.63 (.243)	4.85 (.307)	3.90 (.284)
Stroke	7.61 (.420)	4.57 (.383)	3.99 (.366)	8.74 (.331)	5.11 (.419)	4.59 (.389)

Notes: FU = follow-up.

Table 10. Results from split-plot, repeated measures ANCOVA examining differences in DRS scores.

SV	SS	df	MS	F	p	partial η^2	OP
Covariates							
Time since injury	17.24	1	17.24	4.02	.047	.036	.511
Length of stay	86.07	1	86.07	20.07	<.001	.157	.993
Program Type	25.39	1	25.39	5.92	.017	.052	.674
Between-Subjects Effects							
Etiology	3.82	1	3.82	0.89	.347	.008	.155
Error (subjects within group)	463.27	108	4.29	--	--	--	--
Within-Subjects Effects							
Time	214.15	1.77	120.80	49.89	<.001	.316	1.000
Time*Etiology	5.011	1.77	2.83	1.17	.309	.011	.240
Time*Time since injury	56.86	1.77	32.07	13.25	<.001	.109	.995
Time*Length of stay	1.35	1.77	0.76	0.31	.704	.003	.097
Time*Program type	7.2	1.77	4.06	1.68	.193	.015	.329
Error (residual)	462.46	191.46	2.42	--	--	--	--

Notes: SV = source of variance, SS = sum of sqaures, df = degress of freedom, MS = mean sqaure, OP = observed power.

Table 11. Results from split-plot, repeated measures ANCOVA examining differences in SRS scores.

SV	SS	df	MS	F	p	partial η^2	OP
Covariates							
Time since injury	5.58	1	5.58	1.55	.216	.014	.235
Length of stay	59.48	1	59.48	16.53	<.001	.133	.981
Program Type	14.08	1	14.08	3.91	.050	.035	.500
Between-Subjects Effects							
Etiology	3.03	1	3.03	0.84	.361	.008	.149
Error (subjects within group)	388.60	108	3.60	--	--	--	--
Within-Subjects Effects							
Time	380.89	1.85	206.10	68.23	<.001	.387	1.000
Time*Etiology	4.42	1.85	2.39	0.79	.446	.007	.178
Time*Time since injury	90.01	1.85	48.70	16.12	<.001	.130	.999
Time*Length of stay	5.04	1.85	2.73	0.90	.400	.008	.198
Time*Program type	23.90	1.85	12.93	4.28	.017	.038	.717
Error (residual)	602.93	199.59	3.02	--	--	--	--

Notes: SV = source of variance, SS = sum of sqaures, df = degress of freedom, MS = mean sqaure, OP = observed power.

Table 12. Mann-Whitney U test results: differences in CHART-SF subscale scores at six-month follow-up by etiology.

	TBI (N=67)		CVA (N=47)					
CHART-SF Subscale	**MR**	**SR**	**MR**	**SR**	**U**	**Z**	**p**	**r**
Physical Independence	62.03	4466.00	49.74	2089.00	1186.00	-2.78	.004	-.26
Cognitive Independence	59.53	4286.00	54.02	2269.00	1366.00	-0.87	.193	-.08
Mobility	62.13	4473.00	49.57	2082.00	1179.00	-2.02	.022	-.19
Occupational	60.37	4346.50	52.58	2208.50	1305.50	-1.22	.112	-.11
Social Integration	59.69	4297.50	53.75	2257.50	1354.50	-1.09	.138	-.10

Notes: *significant differences at p<.05, **signifcant group differences at p<.01, MR = mean rank, SR = sum of ranks, U = Mann-Whitney U test statisitc, Z = test statistic z-score, p = 1-tailed exact significance, r = effect size (Z/√N).

Table 13. Hierarchical logistic regression results.

Dependent Variable	Predictor Variable	Model 1						Model 2					
		Model Statistics		Coefficient Statistics				Model Statistics		Coefficient Statistics			
		χ^2	R^2	β	W	OR	CI	χ^2	R^2	β	W	OR	CI
CHART-PHY	**Block A**	12.52*	0.17					12.52*	0.17				
	Time Since Injury			-0.004	6.18*	0.996	.993-.999			-0.003	3.21	0.997	.994-1.000
	Admission DRS			-0.119	4.11*	0.820	.676-.993			-0.112	0.97	0.894	.716-1.117
	Program type			0.505	0.47	1.657	.391-7.017			0.918	1.29	2.504	.514-12.189
	Length of stay			-0.103	5.28*	0.987	.977-.998			-0.002	8.48**	0.978	.964-.993
	Block B	--	--					24.60**	0.31				
	Age			--	--	--	--			-0.081	6.57*	0.922	.867-.981
	Education			--	--	--	--			0.052	0.21	1.053	.846-1.311
	No. of health comorbidities			--	--	--	--			0.566	3.25	1.762	.952-3.260
	Block C	27.28***	0.34					36.81***	0.44				
	Etiology			-2.225	11.78**	0.105	.029 - .380			-2.450	9.67**	0.086	.018-.404
CHART-COG	**Block A**	37.67***	0.40					37.67***	0.40				
	Time Since Injury			-0.013	9.39**	0.987	.979-.995			-0.016	9.90**	0.984	.974-.994
	Admission DRS			-0.340	5.45*	0.712	.535-.947			-0.381	6.18*	0.683	.506-.923
	Program type			-0.303	0.23	0.738	.212-2.574			-0.186	0.07	0.830	.213-3.238
	Length of stay			-0.006	1.20	0.994	.983-1.005			-0.008	1.83	0.992	.980-1.004
	Block B	--	--					50.20***	0.51				
	Age			--	--	--	--			-0.059	6.05*	0.943	.899-.988
	Education			--	--	--	--			0.067	0.44	1.069	.877-1.303
	No. of health comorbidities			--	--	--	--			-0.189	1.09	0.828	.581-1.181
	Block C	40.54***	0.43					50.35***	0.51				
	Etiology			-0.882	2.73	0.414	.145-1.178			0.281	0.15	1.325	.319-5.494
CHART-MOB	**Block A**	1.11	0.01					1.11	0.01				
	Time Since Injury			0.001	0.36	1.001	.998-1.003			0.001	0.44	1.001	.998-1.003
	Admission DRS			0.036	0.22	1.036	.892-1.204			0.066	0.68	1.069	.913-1.251
	Program type			0.341	0.47	1.406	.531-3.726			0.473	0.85	1.604	.586-4.391
	Length of stay			-0.003	0.46	0.997	.990-1.005			-0.004	1.14	0.996	.988-1.004
	Block B	--	--					8.00	0.09				
	Age			--	--	--	--			-0.031	3.99*	0.970	.941-.999
	Education			--	--	--	--			0.036	0.22	1.037	.893-1.203

Table 13. Hierarchical logistic regression results (continued).

	No. of health comorbidities			--	--	--	--			-0.025	0.03	0.976	.748-1.273
	Block C	3.29	0.04					8.23	0.09				
	Etiology			-0.605	2.12	0.546	.242 - 1.233			-0.230	0.22	0.795	.302-2.092
CHART-OCC	**Block A**	11.91*	0.15					11.91*	0.15				
	Time Since Injury			-0.003	2.11	0.997	.994-1.001			-0.003	2.23	0.997	.993-1.001
	Admission DRS			-0.138	1.51	0.871	.700-1.085			-0.138	1.41	0.871	.694-1.093
	Program type			0.532	0.80	1.703	.530-5.471			0.683	1.18	1.980	.576-6.809
	Length of stay			-0.009	2.61	0.991	.981-1.002			-0.010	3.36	0.990	.979-1.001
	Block B	--	--					17.73*	0.21				
	Age			--	--	--	--			-0.038	3.72	0.963	.927-1.001
	Education			--	--	--	--			0.081	0.79	1.084	.907-1.296
	No. of health comorbidities			--	--	--	--			-0.072	0.18	0.931	.672-1.290
	Block C	12.48	0.15					17.85*	0.22				
	Etiology			-0.364	0.56	0.695	.267-1.810			0.216	0.12	1.241	.364-4.229
CHART-SOC	**Block A**	5.29	0.06					5.29	0.06				
	Time Since Injury			-0.003	5.65*	0.997	.995-.999			-0.003	4.03*	0.997	.995-1.000
	Admission DRS			0.006	0.01	1.006	.859-1.178			0.025	0.09	1.025	.870-1.208
	Program type			-0.154	0.09	0.857	.304-2.412			-0.153	0.08	0.858	.298-2.474
	Length of stay			0.000	0.01	1.000	.992-1.007			-0.001	0.07	0.999	.991-1.007
	Block B	--	--					8.20	0.10				
	Age			--	--	--	--			-0.007	0.16	0.993	.962-1.026
	Education			--	--	--	--			-0.089	1.16	0.915	.779-1.075
	No. of health comorbidities			--	--	--	--			0.156	0.85	1.169	.839-1.627
	Block C	7.45	0.09					9.94	0.12				
	Etiology			-0.627	2.15	0.543	.231-1.235			-0.667	1.71	0.513	.189-1.393

Notes: *significant statistic at p<.05. **significant statistic at p<.01. ***significant statistic at p<.001.

Table 14. Hierarchical linear regression results.

Dependent Variable	Predictor Variable	Model 1					Model 2				
		Model Statistics		Coefficient Statistics			Model Statistics		Coefficient Statistics		
		F	ΔR^2	B	β	t	F	ΔR^2	B	β	t
DRS	**Block A**	20.17***	0.43***				20.17***	0.43***			
	Time Since Injury			0.005	0.350	4.69***			0.005	0.345	4.62***
	Admission DRS			0.437	0.464	6.01***			0.402	0.426	5.56***
	Program type			0.088	0.030	0.32			0.023	0.004	0.05
	Length of stay			0.008	0.202	2.16*			0.010	0.258	2.76**
	Block B	--	--				14.58***	0.07**			
	Age			--	--	--			0.039	0.236	2.92**
	Education			--	--	--			-0.070	-0.076	-1.05
	No. of health comorbidities			--	--	--			0.010	0.007	0.08
	Block C	17.14***	0.02				12.73***	0.00			
	Etiology			0.699	0.133	1.82			0.275	0.052	0.63
SRS	**Block A**	17.76***	0.40***				17.76***	0.40***			
	Time Since Injury			0.005	0.351	4.60***			0.005	0.345	4.62***
	Admission DRS			0.466	0.475	6.01***			0.413	0.421	5.47***
	Program type			0.467	0.087	0.93			0.278	0.052	0.58
	Length of stay			0.005	0.132	1.38			0.008	0.194	2.06*
	Block B	--	--				14.42***	0.09***			
	Age			--	--	--			0.049	0.285	3.51**
	Education			--	--	--			-0.008	-0.009	-0.122
	No. of health comorbidities			--	--	--			0.072	0.047	0.57
	Block C	15.43***	0.02				12.51***	0.00			
	Etiology			0.824	0.150	2.02*			0.107	0.020	0.24

Notes: *significant statistic at p<.05. **significant statistic at p<.01. ***significant statistic at p<.001.

Table 15. Bivariate correlation coefficients between predictor variables and six-month outcome variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Time Since Injury	--	--	--	--	--	--	--	--	--	--	--	--	--
2. Admission DRS	.00	--	--	--	--	--	--	--	--	--	--	--	--
3. Program Type	-.13	-.07	--	--	--	--	--	--	--	--	--	--	--
4. Length of Stay	.08	.26**	.55***	--	--	--	--	--	--	--	--	--	--
5. Age	-.03	.12	-.07	-.15	--	--	--	--	--	--	--	--	--
6. Education	.05	.10	.00	.05	.10	--	--	--	--	--	--	--	--
7. No. of Health Conds.	-.25**	.01	.14	.11	.34***	.00	--	--	--	--	--	--	--
8. CHART-PHY	-.19*	-.22*	.00	-.22*	-.25**	-.11	.01	--	--	--	--	--	--
9. CHART-COG	-.35***	-.27**	-.06	-.30**	-.22*	-.03	-.10	.26**	--	--	--	--	--
10. CHART-MOB	.06	.02	.04	-.01	-.22*	.02	-.13	.22*	.19*	--	--	--	--
11. CHART-OCC	-.17	-.19*	.02	-.20*	-.18	.03	-.08	.18	.45***	.28**	--	--	--
12. CHART-SOC	-.22*	.01	.00	-.04	-.06	-.14	.08	.21*	.34*	.22*	.37*	--	--
13. DRS	.29**	.70***	-.08	.26**	.19*	.08	.03	-.40***	-.42***	.00	-.32***	-.20*	--
14. SRS	.33***	.50***	.07	.32**	.32**	.09	.10	-.44***	-.63***	-.15	-.42***	-.31**	.69***

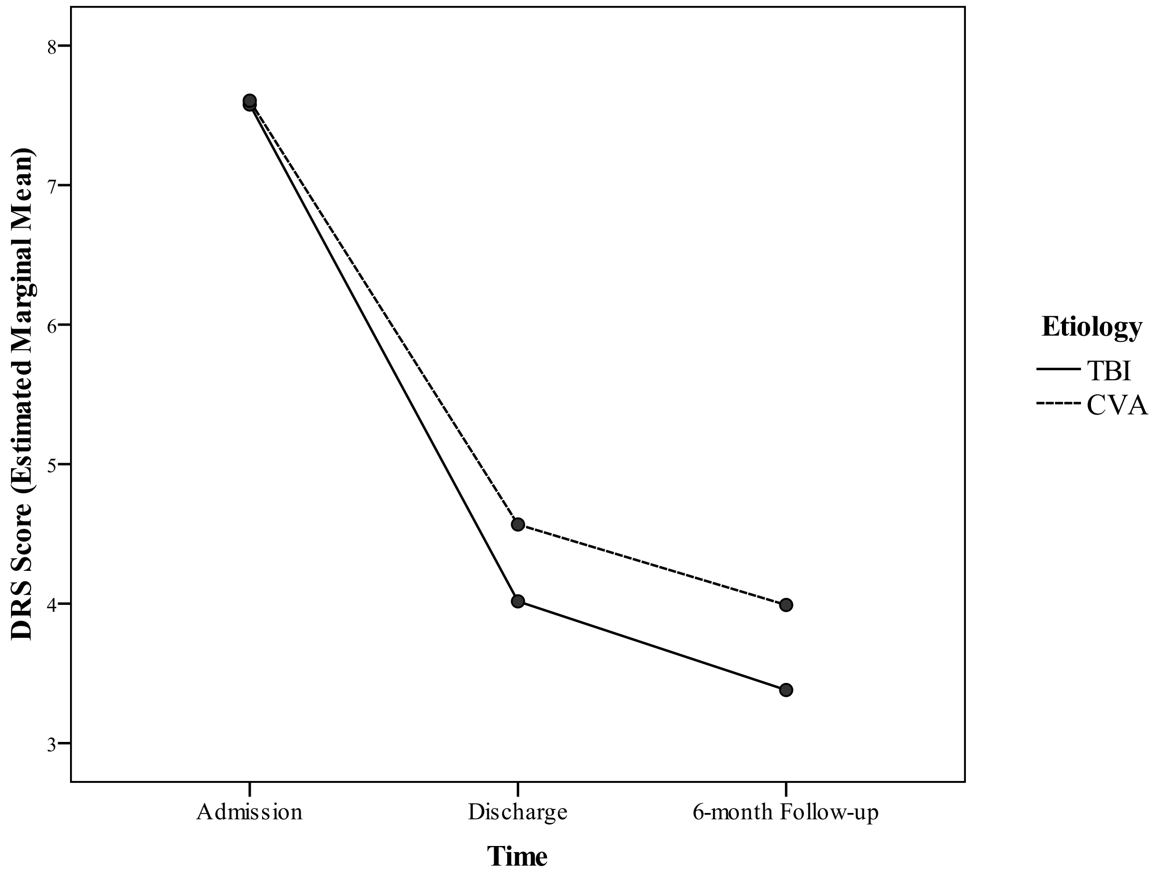
Notes: *significant correlation at p<.05, **significant correlation at p<.01,***significant correlation at p<.001.

Table 16. Partial correlations coefficients between predictor variables and six-month outcome variables, removing the effect of etiology.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Time Since Injury	--	--	--	--	--	--	--	--	--	--	--	--	--
2. Admission DRS	.00	--	--	--	--	--	--	--	--	--	--	--	--
3. Program Type	-.14	-.07	--	--	--	--	--	--	--	--	--	--	--
4. Length of Stay	.07	.26**	.54***	--	--	--	--	--	--	--	--	--	--
5. Age	.02	.14	-.04	-.13	--	--	--	--	--	--	--	--	--
6. Education	.08	.11	.02	.07	.02	--	--	--	--	--	--	--	--
7. No. of Health Conds.	-.22*	.02	.19	.16	.21*	-.09	--	--	--	--	--	--	--
8. CHART-PHY	-.24*	-.23*	-.02	-.25**	-.16	-.06	.14	--	--	--	--	--	--
9. CHART-COG	-.37***	-.27**	-.07	-.31**	-.20*	-.01	-.07	.25**	--	--	--	--	--
10. CHART-MOB	.04	.02	.03	-.02	-.18	.05	-.08	.19*	.18	--	--	--	--
11. CHART-OCC	-.18	-.19*	.01	-.21*	-.17	.04	-.06	.17	.44***	.27**	--	--	--
12. CHART-SOC	-.23*	.01	-.01	-.04	-.02	-.13	.13	.19*	.33*	.21*	.37*	--	--
13. DRS	.30**	.70***	-.08	.26**	.18	.07	.01	-.40***	-.42***	.01	-.32***	-.20*	--
14. SRS	.35***	.51***	.08	.33**	.31**	.08	.07	-.44***	-.63***	-.14	-.42***	-.30**	.68***

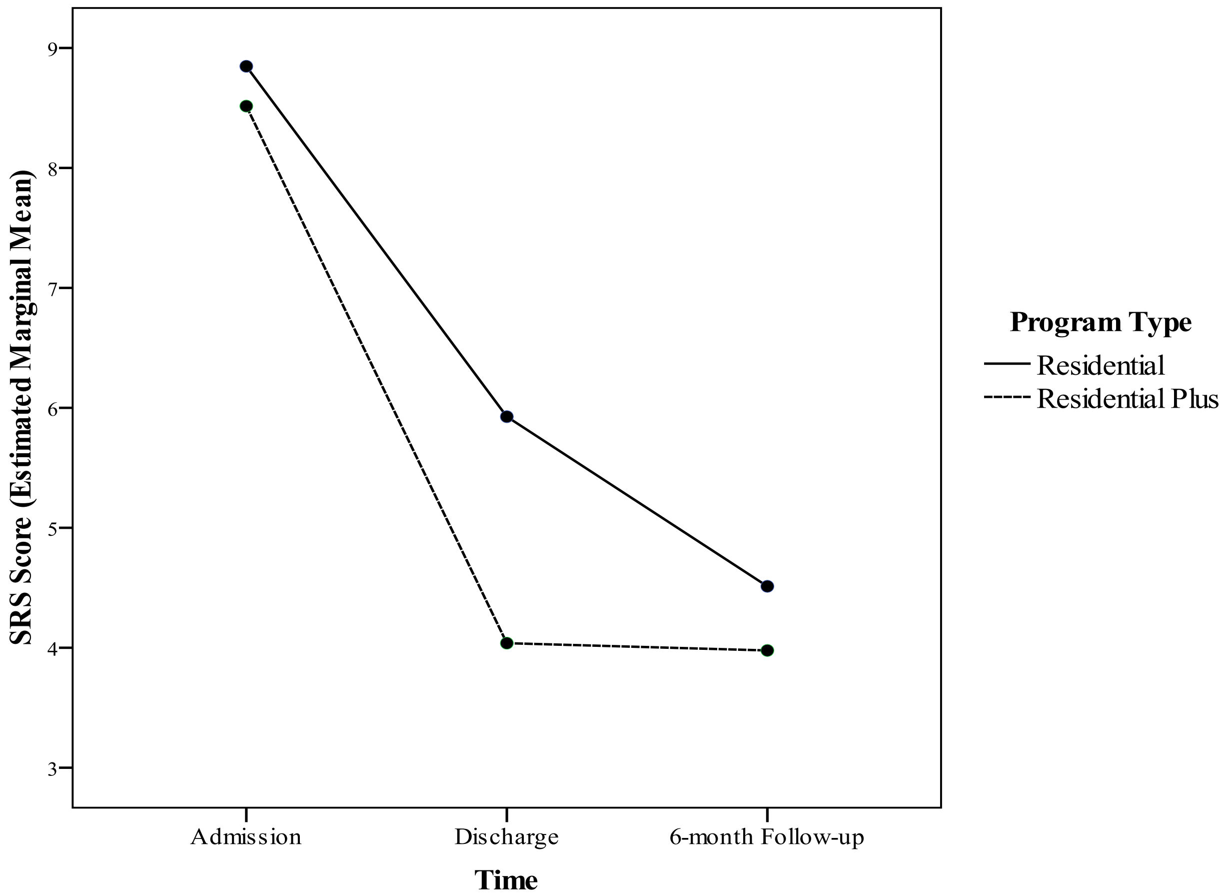
Notes: *significant correlation at p<.05, **significant correlation at p<.01,***significant correlation at p<.001.

Figure 1. Change in adjusted DRS scores over time by etiology.



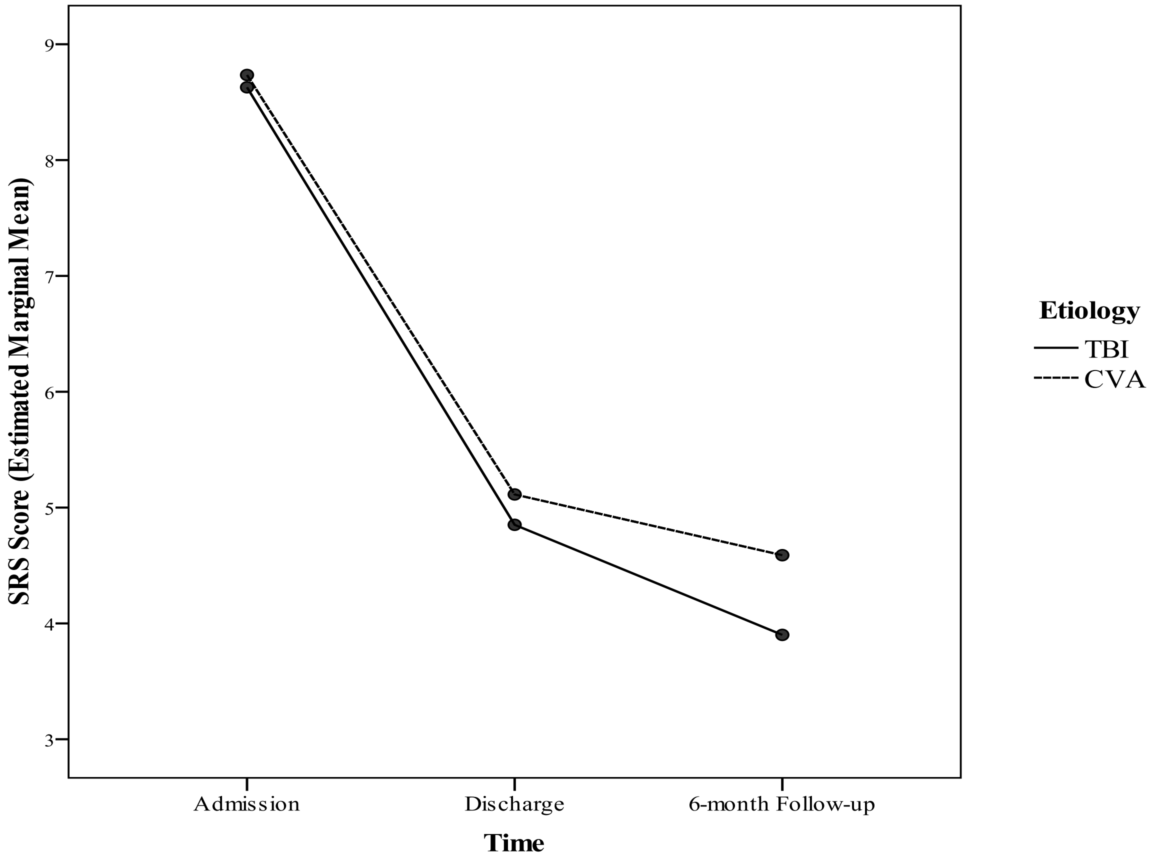
Note: Covariates appearing in the model are evaluated at the following values: time since injury = 152.22 days, length of stay = 115.03 days.

Figure 2. Change in adjusted SRS scores over time by program type.



Note: Covariates appearing in the model are evaluated at the following values: time since injury = 152.22 days, length of stay = 115.03.

Figure 3. Change in adjusted SRS scores over time by etiology.



Note: Covariates appearing in the model are evaluated at the following values: time since injury = 152.22 days, length of stay = 115.03 days