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Traumatic Brain Injury in Adolescence: The Relationship between High School Exiting and Future Productivity

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Traumatic Brain Injury in Adolescence:
The Relationship between High School Exiting and Future Productivity

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
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Table of Contents

List of Tables	iv
List of Figures	v
Abstract	vi
Chapter 1: Introduction	1
Statement of the Problem	1
Theoretical Framework	3
Purpose Statement, Aims, and Research Questions	5
Significance and Implications	6
Definitions of Key Terms	7
Diploma	7
Dropout	7
GED	7
High School Exiting Type	7
Neurorehabilitation	7
Post-Traumatic Amnesia	8
Productivity	8
Traumatic Brain Injury	8
Chapter 2: Review of the Literature	9
Traumatic Brain Injury	9
Prevalence and Incidence of Traumatic Brain Injury	9
Pathophysiology of Traumatic Brain Injury	10
Impairment after Traumatic Brain Injury	11
Neurocognitive	12
Psychosocial	13
Continuum of Care	15
Productivity after Adolescent Traumatic Brain Injury	22
Productivity after Adult Brain Injury	26
High School Exiting	33
High School Exiting Types	35
High School Exiting Rates	38
High School Exiting Rates for Students in Special Education	39
High School Exiting Rates for Students with a Traumatic Brain Injury	41
High School Exiting and Productivity	43
Literature Summary	46
Chapter 3: Method	47
Research Question 1	49

Research Question 2	49
Research Question 3	49
Research Question 4	49
Research Question 5	49
Participants	50
Data Source – Traumatic Brain Injury Model Systems Database	50
Inclusion/Exclusion Criteria and Justification	53
Traumatic Brain Injury Model Systems Criteria	53
Study Specific Criteria	54
Variables	56
High School Exiting Type	56
Outcome Variables –Productivity	58
Statistical Control Variables	59
Sex	59
Race	60
Problematic Pre-injury Substance Use	60
Pre-injury Special Education	61
Pre-injury Working Problems	61
Pre-injury Learning Problems	61
Urbanicity	62
Insurance Type	62
Injury Severity	62
Functioning at Neurorehabilitation Discharge	63
Mechanism of Injury	63
Acute Length of Stay	64
Rehabilitation Length of Stay	64
Sample Descriptives	64
Procedures	66
Institutional Review Board	67
Analysis Plan	67
Study Design	67
Analysis of Sampling Bias	67
Analysis of Missingness	68
Analyses of Control Variable Interrelatedness	68
Selection of Variables for Regression Modeling	68
Analysis of Control Variable and Outcome Variable Interrelatedness	69
Research Question 1 Analysis	69
Research Question 2 Analysis	69
Research Question 3 Analysis	69
Research Question 4 Analysis	69
Research Question 5 Analysis	70
Chapter 4: Results	71
Missingness	71
Sampling Comparisons	71
Research Question 1	73

Research Question 2	73
Control Variable Interrelatedness	75
Final Control Variable Selection for Regression Analyses	76
Research Question 3, 4, and 5	76
Chapter 5: Discussion	80
Aim 1 – Findings and Implications	80
Aim 2 – Findings and Implications	89
Limitations	92
Conclusion	93
References	95

List of Tables

Table 1.	Function Independence Measure Item Responses	33
Table 2.	Recoding of Hours Productive	59
Table 3.	Sample Descriptives: Categorical	65
Table 4.	Sample Descriptives: Noncategorical	66
Table 5.	Sample Attrition Comparisons	72
Table 6.	Comparison by Exiting Type: Categorical	74
Table 7.	Comparison by Exiting Type: Noncategorical	75
Table 8.	Models of Productivity	76

List of Figures

Figure 1. Map of TBIMS Center Locations	53
Figure 2. Flow Diagram	57

Abstract

Traumatic brain injury (TBI) is the leading cause of death and disability among children and adolescents. Brain injury survivors are often left with persistent impairments that have the potential to impede daily functioning, delay or prevent the attainment of developmental milestones, and subsequently limit future productivity in adulthood. A shared goal of both neurorehabilitation and the educational system is to prepare youth for a productive adulthood with both systems of care having substantial, yet independent, literature bases regarding factors associated with productivity (e.g., engagement in employment or post-secondary education). It is currently assumed that because type of high school exiting (e.g., diploma, GED, dropout) is related to productivity for the general population, it also is related to productivity for adolescents with a serious TBI. It is possible that the factors outlined in the TBI literature account for the majority of the variance in this relationship and that exiting has no unique relationship with future productivity for this neurologically compromised population. As such, the purpose of this study was to explore the intersection of TBI and high school exiting.

This study was a secondary analysis of the Traumatic Brain Injury Model Systems (TBIMS) database and featured a sample ($n = 202$) of 16 to 18-year-olds who were enrolled in high school when they sustained a moderate to severe TBI and subsequently attended inpatient neurorehabilitation. All participants in this study suffered their injuries between 4/1/2003 and 10/1/2010. The first aim of this study was to describe the rates of high school exiting for students with a moderate or severe TBI who attended inpatient neurorehabilitation and to examine group differences (e.g., race, insurance type, injury severity). Currently, there are no known data

regarding rates for type of high school exiting (diploma, GED, dropout) or group differences for this population. This study found rates of 83% diploma, 5% GED, and 12% dropout. These rates are striking as they mirror data reported for the general student population. When examining group differences, several factors appeared to be more likely associated with earning a diploma (i.e., White, not receiving Medicaid, no pre-injury learning problem, no pre-injury learning problem, injury severity, higher motor functioning at rehabilitation discharge, acute length of stay) and others with GED (i.e., pre-injury learning problem, pre-injury substance use problem) or dropout (i.e., nonWhite, receiving Medicaid, pre-injury learning problem, lower cognitive functioning at rehabilitation discharge). In this study, variables associated with diploma were conceptualized as protective factors and variables associated with dropout conceptualized as risk factors. Findings from aim one (rates, group differences) are foundational data regarding high school exiting for students with a TBI. These data have the potential to provide normative reference, instill hope, spur collaboration between medicine and education, provide targets for intervention and policy, and serve as the foundation for future research.

The second aim of this study was to examine if exiting type has a unique relationship with future productivity. Productivity was defined as hours per week engaged in post-secondary education and/or employment. Results indicated that exiting type (i.e., diploma) had a unique relationship with total productivity and educational productivity but not employment productivity after TBI. Employment productivity was better explained by several established predictors of productivity (race, pre-injury special education status, post-traumatic amnesia, functioning at rehabilitation discharge). The data from this study provide preliminary evidence that for students who attend inpatient neurorehabilitation after a serious TBI, earning a diploma is attainable, successful exiting can be promoted, and that earning a diploma is related to

outcome (i.e., productivity). Overall, findings from this study provide foundational data that have the potential to aid in prognostication, serve as targets for intervention, and deserve further scientific inquiry.

Chapter 1: Introduction

Statement of the Problem

Traumatic brain injury (TBI) is the leading cause of death and disability among children and adolescents in the U.S. (Centers for Disease Control and Prevention [CDC], 2016). The CDC (2011) estimates that approximately 182,000 children and adolescents between the ages of 4 and 19 years are hospitalized or visit the emergency room annually after suffering a significant TBI; an additional 4,000 die annually from their injuries. Among youth who survive their injuries, approximately 20,000 annually re-enter school annually with persistent disabilities (Ylvisaker, Todis, & Glang, 2001). In the U.S. educational system, an estimated 130,000 students are in need of special education services after experiencing a TBI (Glang, Tyler, Pearson, Todis, & Morvant, 2004). In this study, moderate and severe brain injuries are the focus and can be defined as an injury resulting from an environmental event that causes physical damage to brain tissue often resulting in significant functional disability.

Adolescents who survive significant brain injuries are often faced with significant cognitive, emotional, and physical impairments resulting in a reduction of independent functioning. These impairments have the potential to disrupt, or completely eliminate, the possibility of attaining age-appropriate developmental milestones including learning to drive, cultivating meaningful interpersonal relationships, learning academic material, acquiring vocational skills, and graduating high school (Semrud-Clikeman, 2010). These developmental disruptions occur at a time when adolescents are typically gaining autonomy and consolidating skills in preparation for transitioning from adolescence to early adulthood (Brenner et al., 2007).

A key outcome for both students with a TBI and non-injured students is productivity in adulthood. Accordingly, productivity is a shared goal of both the educational system and brain injury neurorehabilitation, and is often operationalized as engagement in employment and/or post-secondary education.

Currently, there is a wealth of literature regarding the association of high school exiting type (e.g., diploma, GED, dropout) and productivity in adulthood among the general student population. There also is a wealth of literature regarding factors (e.g., demographics, pre-injury functioning, injury severity, post-injury functioning) that are associated with productivity after TBI. What is glaringly missing is the link between these two related, but independent, literature bases. To date, there are no data regarding the rates of high school exiting for adolescence with a TBI who attended inpatient neurorehabilitation, nor are there any data regarding differences between who exits with a diploma, GED, or drops out. Differences explored included a priori variables linked to productivity (demographics, pre-injury functioning, injury severity, post-injury functioning) and descriptive/potentially confound variables (Medicaid status, urbanicity, length of stay, mechanism of injury). Additionally, there is no direct empirical evidence to support that high school exiting type is associated with future productivity for adolescents who suffered a moderate or severe TBI after accounting for known predictors of productivity after TBI. It is possible that known predictors of productivity after TBI (demographics, pre-injury functioning, injury severity, functioning at discharge) account for the majority of the variance in future productivity. These are important questions as they have the potential to inform hospital-to-school transitioning and goal-planning (e.g., practice, research, policy) for adolescents returning to high school after a significant TBI.

Theoretical Framework

Developmental theory posits that the progression through life exists in stages (Thomas & Segal, 2006). Each stage is comprised of typical patterns of behavior, and typical capacities gained. Erik Erikson was a developmental psychologist who is best known for his seminal work on the theory of psychosocial development. He proposed that individuals pass through nine stages from infancy to death (Erikson & Erikson, 1998). During each of these stages the individual confronts and hopefully overcomes challenges that prepare them for the next stage. These stages are linear in nature with the culmination of successful development being a healthy and socially well-adjusted adult. If the stage-specific challenges are not successfully overcome individuals may experience impaired development, which manifests as social dysfunction and may confound developmental stage progression. For typical adolescents, the literature is overwhelming that high school exiting (dropout vs. diploma) is a key developmental milestone/challenge, with graduation being associated with a range of positive outcomes and dropout associated with relatively poor outcomes (Berkold, Geis, & Kaufman, 1998; Cameron & Heckman, 1991; Hull, 2009; Kienzel & Kena, 2006; Julian & Kominski, 2011; Wagner et al., 2005). For adolescents with a TBI, developmental stages and milestones are considered equally as important in theory (Brenner et al., 2007), but there is no direct empirical evidence to support that high school exiting type is a meaningful developmental milestone for this population. Overall, developmental theory provides a stage-based framework for human development that emphasizes the successful completion of one stage in preparation for the next. In this study, the key stage/milestone/challenge is high school exiting.

Currently in the TBI literature a temporal lens is often utilized to model a host of important outcomes (e.g., productivity, mental health, physical health, cognitive recovery,

biology). Variables included in statistical modeling often are demographics such as sex and race, as well as pre-injury factors such as psychopathology, substance use, education, health, engagement in social activities, cognition, behavior, and functioning (Gary et al., 2009; Todis, Glang, Bullis, Ettel, & Hood, 2011; Wilmott, Spitz, & Ponsford, 2015). Next, researchers often include variables related to injury severity as well as acute and post-acute recovery indicators. These factors may include the Glasgow Coma Scale, post-traumatic amnesia, neuroimaging, disability on admission, cognitive testing, and functioning at discharge to name a few (Gary et al., 2009; Todis, Glang, Bullis, Ettel, & Hood, 2011; Wilmott, Spitz, & Ponsford, 2015). After these variables are explored, researchers include factors that happen after the post-acute phase but before the outcome of interest. For example, these variables could be processing speed at one-year post injury when modeling the outcome of five-year productivity, or substance abuse two years post-injury when examining independent functioning four-years post-injury. These widely used and accepted temporally-oriented methods of modeling approximate a developmental view of injury modeling as they take into account stage-based processes from pre-injury, injury, acute phase, sub-acute phase, chronic phase, and outcomes. This is similar to the stage-to-stage developmental lens pioneered by Erik Erikson and utilized in psychology and other social sciences (Erikson & Erikson, 1998). In this study, the developmental lens of recovery includes empirically relevant characteristics of demographics, pre-injury characteristics, injury severity, and sub-acute functioning as control variables to explore if a unique association exists between the developmental milestone of high school exiting and five-year productivity after moderate to severe adolescent TBI.

Purpose Statement, Aims, and Research Questions

The purpose of this study was to explore the intersection of moderate and severe TBI and high school exiting type (i.e., diploma, GED, dropout) for adolescents who attended inpatient neurorehabilitation prior to high school exiting. The first aim of this study was to describe the rates at which these injured adolescents exit high school by dropout, GED, or diploma, and to explore differences between these three groups. The second aim of this study was to explore if high school exiting type is uniquely associated with future productivity for this population. Productivity was defined as hours per week engaged in post-secondary education and/or employment.

Research Question 1: *What are the rates of high school exiting (e.g., diploma, GED, dropout) for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?*

Research Question 2: *Do exiting groups differ across descriptive variables and variables related to productivity (demographics, pre-injury functioning, injury severity, functioning at discharge) for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?*

Research Question 3: *What is the unique relationship between high school exiting type and total weekly hours productive (i.e., hours engaged in post-secondary education and employment) at five-years post-injury for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?*

Research Question 4: *What is the unique relationship between high school exiting type and total weekly hours engaged in employment at five-years post-injury for adolescents who suffered a*

moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

Research Question 5: *What is the unique relationship between high school exiting type and total weekly hours engaged in postsecondary education at five-years post-injury for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?*

Significance and Implication

Traumatic brain injury is the leading cause of death and disability among children and adolescents in the U.S. (CDC, 2016) with 20,000 transitioning back to school annual (Ylvisaker, Todis, & Glang, 2001). In total, it is estimated that 130,000 students are in need of special educational services because of lasting impairments caused by their brain injury (Glang et al., 2004). Although re-entry means the discharge from medical care to school, the process of recovery and the factors that influence it are ongoing. A primary goal of both the medical system and the educational system is to prepare youth to become productive adults. In the medical and rehabilitation literature there has been extensive inquiry and discovery relating to factors associated with future productivity. The same is true in the educational literature with one of the key variables associated with productivity in adulthood being high school exiting type. Although these two systems are linked by population and the shared goal of producing productive adults, it is unknown how many adolescents with a TBI who attended inpatient neurorehabilitation exit with a diploma, GED, or dropout, difference between these group, and if exiting is even associated with outcome for this unique population. Accordingly, this study is significant as it fills glaring gaps in the literature regarding the description of exiting and the relationship of exiting with outcome for students with a TBI who attended inpatient neurorehabilitation.

Findings from this study are the first step in understanding if the assumption that graduating high school is appropriate to be applied to students with a significant TBI. This study forms the foundation of future studies through the description of exiting rates and group difference as well as linking exiting to outcome. This study provides normative exiting rates and prediction that professionals can utilize to communicate expectations to the injured, their families, schools, and other stakeholders. Risk factors and protective factors related to exiting are identified that may open the door for intervention through clinical intervention or policy. Additionally, preliminary evidence is provided to evaluate the implicit assumption that high school exiting matters for students with a TBI. Overall, this study informs practice, policy, and future research as it relates to neurorehabilitation planning, school re-entry and goal planning, and the success of injured students transitioning from high school to a productive adulthood.

Definition of Key Terms

Diploma. Document awarded to students through completion of high school requirements.

Dropout. Students who attend primary or secondary education but do not receive a GED or diploma.

GED. A type of high school exiting defined as earning the Certificate of High School Equivalency by passing the Test of General Educational Development (GED).

High School Exiting Type. The award, or lack thereof, upon leaving secondary education. The three options include a high school diploma, GED, or by dropping out.

Neurorehabilitation. Medical services provided which have the goal of facilitation recovery of the nervous system and to minimize or accommodate for resulting functional deficits.

Post-Traumatic Amnesia. Time from incurring a traumatic brain injury until the individual returns to orientation and can form and recall new memories.

Productivity. Engagement in employment and/or post-secondary education.

Traumatic Brain Injury. An injury resulting from an environmental event which causes physical damage to brain tissue often resulting in significant functional disability.

Chapter 2: Literature Review

Traumatic Brain Injury

Traumatic brain injury (TBI) is the leading cause of death and disability among children and adolescents in the U.S (CDC, 2016). TBI results from an environmental event that causes physical damage to brain tissue, often resulting in significant disability. In this section, the prevalence of TBI, as well as its pathophysiology, dysfunction, continuum of care, impact on productivity, and known predictors of productivity post-TBI will be discussed.

Prevalence and Incidence of Traumatic Brain Injury. Children and Adolescents are at particular risk for both incurring a TBI and experiencing significant disability resulting from a TBI (CDC, 2016). The total incidence of TBI in the U.S. is thought to range between 1.5 and 3.5 million injuries annually (CDC, 2016; Coronado et al., 2012). Youth are at particular risk for incurring a TBI, with approximately 182,000 children and adolescents between the ages of 4 and 19 years visiting the emergency room and/or being hospitalized annually after suffering a significant TBI (CDC, 2011). Approximately 20,000 youth with persistent disability from a TBI re-enter school each year (Ylvisaker, Todis, & Glang, 2001) and an estimated 130,000 students in the U.S. are in need of special education after TBI (Glang, Tyler, Pearson, Todis, & Morvant, 2004). An additional 4,000 die from their injuries annually. These numbers may be gross underestimates. Finkelstein, Corso, and Miller (2006) estimated the population incidence by accounting for the significant amount of individuals who do not seek medical treatment in addition to reported TBIs. They found that roughly 50 million TBIs occurred in the U.S. last year which is an incidence rate of approximately 0.18%. This is drastically larger compared to the 1.5

to 3.5 million injuries estimated by the CDC (2016) and Coronado and colleagues (2012). Among youth between the ages of 15 and 25 years, Finkelstein and colleagues (2006) found that approximately 218,000 injured youth presented for medical care while an estimated 8.6 million injuries went unreported. The total incidence for this age range was 0.24%, which was the highest incident rate when compared to all other age ranges. In addition to the sheer volume of annual injuries, TBI associated disability often develops into a chronic condition that necessitates a lifetime of support.

The CDC (2016) estimated that roughly 5.3 million Americans are currently living with some form of chronic TBI-related disability. Finkelstein, Corso, and Miller (2006) estimated that the reported and unreported TBIs that occurred during the year 2000 will cost society \$80.2 billion for a lifetime of services. The lifetime cost of medical care for those aged 15 to 24 was \$12.9 billion while the loss in productivity for this age range was \$18.2 billion. Interestingly, those who were not hospitalized cost society more and lost more in productivity than those who were hospitalized. With a high prevalence, associated acute and chronic disability, and substantial economic cost, TBI is considered a major public health problem that the CDC has targeted for systemic prevention, identification, and treatment.

Pathophysiology of Traumatic Brain Injury. Traumatic brain injury is defined as an alteration of brain function or observable brain pathology caused by an external force (Menon, Schwab, Wright, & Maas, 2010). After the precipitating event, brain tissue may undergo acute cell death and/or axonal injury (Croall et al., 2014; Smits et al., 2011) as well as acute changes in connectivity (Shumskaya, Andriessen, Norris, & Vos, 2012), blood flow (Maugans, Farley, Altaye, Leach, & Cecil, 2012), and metabolic changes (Giza & Hovda, 2001). Subsequent non-acute brain pathology, also called secondary brain injury, may persist into the sub-acute and

chronic phase of recovery resulting from hypoxia, hypertension, hypotension, neurotoxic cascades, calcium channel disturbance, oxygen free radical production, hematoma formation, infection, and seizure (Chesnut et al., 1993; Murthy, Bhatia, Sandhu, Prabhakar, & Gigna, 2005). Brain injury severity has been found to be associated with survival and degree of disability (Fay et al., 1994; Jaffe et al., 1993; Michaud, Rivara, Grady, & Reay, 1992). Overall, the pathophysiology of TBI is a complicated and evolving process characterized by acute traumatic damage followed by secondary injury.

Impairment after Traumatic Brain Injury. Injury to the brain can result in a constellation of symptoms and deficits. These changes in central nervous system functioning may occur across the stages of recovery (i.e., acute, subacute, chronic) and may wax and wane over time. Domains of dysfunction may include cognition (Schretlen & Shapiro, 2003; Yeates et al., 2002), social interactions (Ryan et al., 2014; Yeates et al., 2013), behavior (Fletcher et al., 1996; Li & Liu, 2013; Taylor et al., 2002), psychopathology (Bombardier et al., 2010; Jorge et al., 2004; Max et al., 1997), sleep (Castrionta et al., 2007; Mathias & Alvaro, 2012; Orff, Ayalon, & Drummond, 2009), physical health (Andelic et al., 2010; Iverson, Pogoda, Gradus, & Street, 2013), quality of life (Pagulayan, Temkin, Machamer, & Dikmen, 2006; Stancin et al., 2002) and academic achievement (Arroyos-Jurado, Paulsen, Ehly, & Max, 2006; Ewing-Cobbs et al., 2004; Taylor et al., 2002). Taken as a whole, TBI represents a significant injury to the brain that often negatively impacts an individual's ability to interact with their environment efficiently (e.g., education, vocation, social, activities of daily living). Although there are many ways that TBI impairs functioning, perhaps the two most common forms of impairment can be found in the domains of neurocognition and psychosocial functioning.

Neurocognition. Neurocognition consists of a set of abilities that are closely associated with brain structures and neural circuitry. Common neurocognitive domains include executive functioning, perceptual-motor functioning, language, attention, social cognition, learning and memory (American Psychiatric Association, 2013). In moderate and severe TBI, specific areas of brain tissue are injured or destroyed. Research has demonstrated that there is a dose-response between injury severity and level of neurocognitive impairment (Babikian & Asarow, 2009; Mathias & Patricia, 2007; Ruttan et al., 2008). Subsequently, cognitive impairments are believed to be the main factors behind educational difficulties after TBI (Laxe, Leon, Salgado, & Zabaleta, 2015).

Babikian and Asarow (2009) conducted a meta-analysis of neurocognitive outcomes after pediatric TBI. In this meta-analysis, 28 studies published between 1988 and 2007 met inclusion criteria. Neurocognitive outcomes were examined at three-time points: Time 1 (0-5 months post-injury), Time 2 (6-23 months post-injury), and Time 3 (24+ months post-injury). Findings were grouped by injury severity (i.e., mild, moderate, severe). Babikian and Asarow found that individuals with mild injuries showed few, if any, lasting neurocognitive impairments. Persons with moderate injuries had poorer neurocognitive outcomes than those with mild injuries and better outcomes than those with severe injuries. Those with moderate injuries were more similar in terms of neurocognitive outcome with severe injuries than mild injuries, specifically, processing speed and intellectual functioning at Time 1. At Time 1 youth with moderate injuries showed serious impairments in intellectual functioning, processing speed, and immediate visual memory. At Time 3 youth with moderate injuries showed impairments in intellectual functioning, attention, and executive functioning. Although still impaired, significant recovery between Time 1 and Time 2 was observed in processing speed and performance intelligence. At

Time 1 youth with severe brain injuries showed impairments in intellectual functioning, processing speed, attention, and memory. At Time 3 severely injured youth continued to have problems with intellectual functioning, processing speed, attention, and memory and had developed new deficits in the domains of working memory, fluency, execution functioning, and visual perception. Although still impaired, between Time 1 and Time 3, severely injured youth showed significant recovery in intellectual functioning, processing speed, and working memory. Youth with severe injuries showed some neurocognitive recovery but fell further behind peers over time. In general, those with moderate and severe TBIs showed significant and persistent impairments across a range of neurocognitive outcomes.

The findings from Babikian and Asarow (2009) are similar to two comparable meta-analyses examining neurocognitive functioning after moderate or severe TBI. Ruttan and colleagues (2008) utilized 16 studies published between 1966 and 2007 and found that individuals with moderate and severe TBI had impairments in neurocognitive functioning in the post-acute (6 to 18 months post-injury) and chronic (4.5 to 11 years post-injury) phases of recovery. Similarly, Mathias and Patricia (2007) utilized 41 studies examining attention and processing speed among those with severe TBI and found large and significant deficits in both. Overall, despite the partial recovery of some abilities, these three meta-analyses support the conclusion that moderate to severe brain injury is characterized by significant and lasting impairments in neurocognition.

Psychosocial. Psychosocial problems (e.g., anxiety, depression, behavioral concerns) after a significant brain injury are common. Schwartz and colleagues (2016) compared long-term externalizing behavior problems in children who had suffered a moderate ($n = 42$) or severe ($n = 42$) TBI to children with an orthopedic injury ($n = 50$). Prevalence of behavior problems was

measured at baseline (preinjury), six months, twelve months, and at “extended follow-up.” The extended follow-up had a mean time to measurement of four years post-injury. The presence of behavior problems was defined as clinically significant scores on the Child Behavior Checklist which measures problem behaviors in terms of participation in activities, social relations, and school performance. For children with moderate TBIs, they had similar preinjury behavior problem as controls (24% vs. 20%), and more behavior problems at six months (22% vs. 11%), twelve months (23% vs. 13%), and at extended follow-up (22% vs. 10%). For children with severe TBIs, they had lower preinjury behavior problem than controls (10% vs. 20%), and increasingly more behavior problems at six months (23% vs. 11%), twelve months (31% vs. 13%), and at extended follow-up (36% vs. 10%). Behavior problems after TBI were correlated with post-injury limitations in working memory, adaptive behaviors, school competence, and adverse family outcomes. Overall, children with a TBI had significantly more behavior problems than controls from six months to four years post-injury, which were related to problems in school competence.

Scott and colleagues (2015) conducted a study to identify the emergence of TBI-related psychopathology among children and adolescents (aged 1-17) in early adulthood (aged 18 – 31). Pathology examined were internalizing (depression, anxiety) and externalizing (substance use, antisocial) problems. In this study the sample consisted of individuals with mild TBI (n = 61), moderate/severe TBI (n = 65), and orthopedic injury controls (n = 43). Follow-ups were conducted at least five years post-injury and during early adulthood. In terms of major depressive disorder, controls had the lowest rate (31%) followed by moderate/severe TBI (40%) and mild TBI (53%). Regarding anxiety disorders, controls had the lowest rate (7%) followed by moderate/severe TBI (19%) and mild TBI (28%). In terms of antisocial behaviors, controls had

the lowest rate (10%) followed by mild TBI (18%) and moderate/severe TBI (36%). Regarding substance abuse, controls had the lowest rate (7%) followed by mild TBI (21%) and moderate/severe TBI (34%). Overall, individuals who suffered a TBI in childhood or adolescence showed higher rates of internalizing and externalizing problems in early adulthood when compared to controls.

Continuum of Care. The continuum of care for youth with TBI includes many settings (e.g., community prevention, acute care hospitalization, outpatient rehabilitation, community reintegration). Perhaps the largest and most important aspect of care is prevention that occurs in the community setting. Preventing TBIs from occurring can take many forms; gun safety, motor vehicle safety, city planning, safe sporting regulations, workplace safety, among others. Although prevention is key, injuries still occur, and the remainder of the continuum of care seeks to ensure that the individual survives their injury, limits secondary injury, mitigates permanent disability, increases functioning and adaptive skills, and facilitates community/educational reentry.

The goal of acute medical care is to both decrease the chance of death (Ventura et al., 2010) and to improve functioning (De Guise, Leblanc, Feyz, & Lamoureux, 2005). During acute care, patients with moderate or severe TBI often require immediate neurological evaluation and intervention (Marshall, Bell, Armonda, Ling, 2012). Acute intervention may include airway control, mechanic ventilation, intracranial pressure management, and stabilization of other injuries. The initial goals of acute medical care is to provide clinical stability, preserve neurological functioning, and prevent secondary injury.

When the patient is stable enough, they can be transferred to neurorehabilitation. Rehabilitation after TBI is a complex endeavor and can occur in both inpatient and outpatient

settings with the former being more intensive. The goals of neurorehabilitation after TBI are to improve overall health, decrease the level of disability, increase the level of functioning, and increase the chances for post-injury productivity (Cullen, Vimalasan, & Taggart, 2013; Dumas, Haley, Ludlow, & Rabin, 2002). Common treatments to meet these goals include cognitive retraining, psychotherapy, promotion of a therapeutic milieu, vocational training, family education and therapeutic assistance, and follow-up procedures (Sarajuuri et al., 2005). Neurorehabilitation treatment teams often consist of diverse professionals including medical doctors, physiotherapists, psychologists, social workers, speech and language pathologists, occupation therapists, and other interventionists (Cullen, Vimalasan, & Taggart, 2013; Glenn, 2010). TBI often occurs during the years when individuals are acquiring the skills needed in preparation for adulthood. Subsequently, an emphasis of neurorehabilitation is preparing patients to increase functioning by relearning old and/or acquire new abilities and skills in order to enhance vocational opportunities (Sarajuuri et al., 2005). Many studies have examined the global and specific impacts of neurorehabilitation across a range of outcomes.

A meta-analysis ($k = 115$, $n = 2,014$) by Rohling and colleagues (2009) examined the impact of neurorehabilitation on recovery across various outcomes (e.g., motor deficits, emotion regulation, social interaction, self-sufficiency, employment) and found a large treatment effect ($ES = .71$) for neurorehabilitation compared to a moderate effect for nontreatment controls ($ES = .41$). Additionally, the treatment component of cognitive rehabilitation was found to have a small but significant treatment effect ($ES = .30$), independent of the overall neurorehabilitation treatment effect. Taken as a whole, this meta-analysis supports that neurorehabilitation increases recovery over and above what spontaneously occurs and that cognitive treatments are an effective component of overall treatment.

Using a case-control design, Sarajuuri and colleagues (2005) compared an inpatient neurorehabilitation program specialized for patients with TBI (n = 19) to conventional care (n = 20) on the outcome of productivity. Productivity was categorically defined (productive vs. nonproductive) and operationalized as full-time employed, in school, or participating in organized and meaningful voluntary work. This categorization of outcome was based on self-report and spouse report and compared pre-injury productivity (control variable) vs productivity two years after rehabilitation discharge. The comprehensive and TBI-specific program consisted of a post-acute six-week inpatient program that focused on neuropsychologic rehabilitation and psychotherapy. The control group received rehabilitation care in the general healthcare system. At the two-year follow-up, 89% of those who went to specialized treatment were productive compared to only 55% of controls (odds ratio = 6.96; p = .017). This study provides evidence that specialized TBI rehabilitation programs may increase future productivity of patients with a TBI more than traditional rehabilitation. This study was selected as the TBIMS sample used in this study is a form a specialized TBI rehabilitation.

To further examine the effect of specialized care, Cullen and colleagues (2013) investigated the efficacy of a functionally-based neurorehabilitation program compared to traditional treatment. In this case-matched (n = 69 pairs) research study, two groups were compared. The control group consisted of a historical sample that was treated prior to May 2001. In this group, all subjects received traditional neurorehabilitation in a program that focused on both cognitive and physical impairments. The second group was treated after May 2001 and participated in a functionally-based neurorehabilitation model that specialized treatment based on the dominant impairment, physical or cognitive. Groups were matched for age, injury severity, and time to rehab admission. Matching yielded 29 pairs who primarily had neurocognitive

impairments and 41 pairs who had primarily neurophysical impairments. Although both groups showed functional increases (measured by the FIM) in their primary impairment (i.e., neurocognitive, neurophysical), the group with the specialized treatment demonstrated a more efficient course of treatment. These findings provide further evidence that neurorehabilitation can increase functioning and that targeted treatment can further increase treatment efficacy.

Overall, there is significant evidence that neurorehabilitation positively impacts recovery after moderate and severe TBI. Specifically, the studies described above support that neurorehabilitation is effective (Rohling et al., 2009), increases functioning (Cullen, Vimalasan, & Taggart, 2013), and increases the odds of being productive (Sarajuuri, 2005). Additionally, rehabilitation specialized for TBI (Cullen, Vimalasan, & Taggart, 2013; Sarajuuri et al., 2005) and cognitive rehabilitation (Rohling et al., 2009) appear to be important and effective components of neurorehabilitation. After youth finish rehabilitation they must transition to a new setting, for adolescence this often takes the form of school reentry and it is one of the most critical points in the rehabilitation process (Glang, Ettel, Tyler, & Todis, 2013).

Many issues can arise during the medical to school transition. Far too often hospital to school communication is established late in rehabilitation or is not established at all, information is incomplete, school personnel are unfamiliar with working with students with a TBI, and educational expectations for the student are unknown or unrealistic (Glang, Ettel, Tyler, & Todis, 2013; Savage, DePompei, Tyle, & Lash 2005). To address the collaboration and communication issues several steps can be taken. Semrud-Clikeman (2010) proposed that planning for school reentry should begin as early as possible in the process. Prognostication and early planning help medical professionals know how to prepare the student best for transfer to the school and it allows the school to anticipate student needs, calibrate expectations, and predict service needs.

Areas to consider include what can the student do or not do, what kind of school educational environment will best suit their needs, select an appropriate teacher(s), and anticipate the need to help facilitate peer interactions upon reentry. Glang and colleagues (2013) built upon this by recommending that school staff observe the student in the medical setting and to attend medical discharge meetings to attain as much information as possible about the student's current and predicted functioning. These steps would also help forge a collaborative relationship that can be revisited in the future should issues arise. Ideally, a TBI hospital-school reentry protocol would exist to guide this process but this is not typical in practice.

Savage, DePompei, Tyler, and Lash (2005) described existing school reentry protocols for students with a TBI (Depompei, Blosser, Savage, & Lash, 2009; Ylvisker & Freney, 1998). Typically in these protocols, one party (medical or educational) would reach out to the other soon after medical admission. Once the communication dyad is established, medical professionals (e.g., medical doctors, neuropsychologists, psychologists, social workers, physical therapists) can pass information on to the school regarding the student's evolving prognosis and functioning so the school can predict recovery and supports needed upon reentry. Specific information transferred from medical to educational professionals may include the anticipated date of discharge, mechanism of injury, current medical condition, behavioral functioning, cognitive functioning, anticipated long-term medical needs (e.g., medications, need for special equipment, accommodations), and anticipated occupational, speech, or physical therapy needs. Two of the key considerations upon reentry to the school are to determine if accommodations or special educational services are needed and what they will include. The likelihood of needing these services for a student with a serious TBI are very high.

Once the decision is made to return the child to school two pieces of legislation underpin the process of helping youth return to school after TBI, the Rehabilitation Act of 1973 and the Individuals with Disabilities Educational Act of 1997 (IDEA). The Rehabilitation Act of 1973 and its subsequent revisions (Americans with Disabilities Act of 1990, Americans with Disabilities Act Amendment act of 2008) are federal laws that authorize state grants to provide educational and vocational training opportunities for individuals with severe disabilities and to provide protections for individuals with disabilities. These “equal opportunity” protections for those with disabilities are similar to those protections established by the Civil Rights Act of 1964 that prohibits discrimination based on sex, race, religion or national origin.

In the schools, Section 504 of the Rehabilitation Act (1973) is particularly pertinent for students reintegrating from the medical setting to the educational setting as it ensures equal access to the learning environment through environmental accommodations. Common accommodations include note-taking, class outlines, course substitutions, extended time, breaking up large tests into a series of smaller tests, permit use of reference materials, adjustments to item response formats (e.g, multiple choice vs. open-ended), scribe or computer use for instruction, separate testing room, tutoring, adjustments to travel between classes (e.g., shorter distance, use of elevator), text to speech software, reduce quantity of work for quality, and audio recording of textbooks (Childers & Hux; 2013; Hux, Bush, Zickefoose, Holmberg, Henderson, Simanek, 2010; Kreutzer & Hsu, 2015). A student can qualify for a 504 plan if they have a physical or mental impairment that substantially limits their ability to participate in a major life activity, such as learning. In almost all cases a severe TBI will warrant a 504 plan. In addition to a 504 plan, students with a TBI can seek special educational services.

The Individuals with Disabilities Education Act (1990), and its subsequent revisions (1997, 2004), are an extension of the Education for all Handicapped Children Act (1975) that mandates that school provide students with a disability a free and appropriate public education that is tailored to their individual needs. The six key component of this law in practice are procedural safeguards, least restrictive environment provision, free and appropriate education, parents and teacher participation, and the individualize education program. To receive special education services under IDEA students must first be identified and evaluated. Students transitioning from rehabilitation to school should automatically be identified based on the known severity of their injury and anticipated impairments. Establishing inter-system communication early as possible can aid in identification and early assessment. Ideally the student could be evaluated for special educational services prior to medical discharge or very soon after medical discharge. Common domains of assessment for students with a TBI include cognition, memory, executive function, attention/concentration, language/verbal learning, visual perception, academic-general, academic-targeted, behavior, social behavior, adaptive behavior, and motor skills (Glang et al., 2013).

If the injured child qualifies for special education services they must receive an individualized and appropriate education through the development and implementation of an individualized educational program (IEP). Based off of the assessment process, the IEP establishes learning goals and strategies and interventions believed to best promote learning individualized to the student's strengths and weaknesses. Components of the IEP may include counseling services, physical or occupational therapy, speech and language therapy, behavioral strategies, teaching modifications, disciplinary procedures, and recommendations for placement

in the least restrictive educational environment. Additionally, by age 16 students in special education must have goals and plans in their IEP relating to post-secondary transitioning.

By law, the post-secondary transitioning plans and goals must help the student from high school to their next stage in life by taking into account that individuals interests, preferences, abilities, and include measurable goals (Glang et al., 2013). Furthermore, the plan should prepare students for their next stage in life through educational instruction, services, experiences, living skills, and goals and preparation related to vocation and/or post-secondary training or education. The spirit of this mandate is to prepare students to lead a fulfilling and productive adulthood.

Productivity after Adolescent Traumatic Brain Injury. Moderate and severe TBI has the potential to drastically decrease the future productivity for adolescents transitioning to adulthood. Although there are currently no known studies exploring if a unique relationship exists between high school exiting type and future productivity after adolescent TBI, there is a nascent literature base examining the rate of future productivity and factors associated with productivity for youth with a TBI. In this section, studies which explore future productivity for youth with a TBI will be described while the more established adult productivity literature base will be discussed in detail later in this document.

Wagner and colleagues (2005) utilized the National Longitudinal Transition Study – 2 dataset to examine the experiences and achievements of youth with disabilities who had exited high school and were transitioning to adulthood (n = 1,828,790). This study included students across 11 of the 13 special educational categories, which includes TBI (n = 5,113). Deafness and developmental delay were not included. In this study, productivity was measured soon after graduation and up to 2-years post injury and was defined as engagement in employment, post-secondary education, or job training. It is of note that productive engagement was liberally

classified in this study and did not take into account volume of activity. For example, employment was defined as working for pay, post-secondary education was defined as taking a course, and job training was defined as receiving training. It was found that 71% of participants classified under the special educational category of TBI were productive upon follow-up. The TBI group ranked six out of the 11 special educational disability classifications in terms of productivity. When the type of productive engagement was broken down for youth with a TBI, 49% were engaged in employment only, 12% were engaged in job training, 8% were employed and in post-secondary education, and 2% participated in post-secondary education only. Out of the 11 other special education categories these rates ranks 2nd, 4th, 10th, and 10th respectively. A second important finding from this study was that functional cognitive skills were significantly related to productivity, such that 86% of high functioning, 71% of moderate functioning, and 32% of low functioning individuals were productive across all categories of disability. Although this study has significant limitations (e.g., lack of TBI severity, liberal criteria for productivity), the findings regarding the rate of productivity, relative productivity, and the influence of cognitive functioning on productivity, are noteworthy.

A later study conducted by Wehman and colleagues (2014) used the same National Longitudinal Transition Study – 2 dataset and took a closer look at the productivity of a subset of students classified in the TBI special education category (n = 200) up to 8 years after exiting. At the time of follow-up, they found that 51% were employed and 73% had been employed at some point between exiting high school and follow-up. They found that transitioning goals for post-secondary education predicted employment. This study has similar limitations as the previous study but contributes to the literature by describing the rate of employment and the influence of the modifiable factor of transitional planning.

Balaban, Hyde, and Colantonio (2009) conducted a similar study where they explored the effects of TBI (mild to severe) on career plan and productivity five years post-injury. Participants ($n = 51$) were between 15 and 19 years of age at injury and had been hospitalized for their brain injury. At five years post-injury 66.7% of the sample was productive with 58.8% employed and 7.8% in school. At follow-up the majority of participants who were working reported working at a job with lower occupational requirements than they had anticipated working prior to their injury. Although this study had a small sample size and limited analyses, it provides evidence that mild to severe brain injury in adolescents has the potential to negatively impact employment opportunities five years post-injury.

Kriel and colleagues (1988) examined the educational attainment (high school graduation, college attendance) and employment of 28 adolescents who were severely injured between the ages of 13 and 18. Follow-up interviews occurred between two and 11 years post-injury when participants were between the ages of 18 and 27 and transitioned into adulthood. When compared to a population reference (same age, same geographical location), the TBI group graduated high school at a lower rate (64.3% vs. 82.9%), attended college at a lower rate (14.3% vs. 27.7%), withdrew from the labor force at a higher rate (35.7% vs. 23.6%), were employed at a lower rate (35.7% vs. 69.9%), and were unemployed at a higher rate (28.6% vs. 6.4%). This study supports that a TBI during adolescence has the potential to negatively influence a range of productivity outcomes in early adulthood.

Wilmott, Spitz, and Ponsford (2015) conducted a longitudinal study with the purpose of identifying the rates and predictors of productivity (postsecondary education, employment) at one-year post-injury. The majority of participants ($n = 145$) in this study had sustained a moderate (31%) or severe TBI (61%) and were between the ages of 13 and 34 years ($M = 18.6$)

at injury. A minority (8%) of the sample had incurred a mild TBI. All participants were engaged in secondary (45%) or postsecondary education (55%) at time of injury. At one-year post-injury, 79% of participants were categorized as productive, with productivity being defined as employed or had returned to education on a full or part-time basis. When examining the 79% who were productive, 60% were engaged in education while 40% were employed. When examining the proportion of those productive vs. nonproductive across a range of variables, significant group differences were found in functional dependence in activities of daily living (ADL; personal, light chores, heavy chores), difficulties in conversation, difficulties in memory, and behavior sequelae (self-centeredness, initiative). When employing multivariate modeling and controlling for sex, education, age at injury, and urbanicity, the strongest predictors of productivity were post-traumatic amnesia (PTA) and behavioral sequelae. Overall, this study provides evidence that injury severity, post-injury behavioral difficulties, and functioning (ADLs, conversation, memory) all seem to play a role in productivity for adolescents and young adults with a significant TBI.

The last study to be discussed in this section was conducted by Todis and colleagues (2011) in which they described the productivity (post-secondary education, employment) of youth with TBI transitioning from high school to adolescence. The majority (52%) of participants ($n = 89$) were between the ages of 15 and 19 at the time of injury with age at injury ranging between 0.05 and 20.25 (mean = 12.01; $SD = 6.30$) years old. The majority of participants (78%) had a severe TBI while a minority (21.3%) had a mild or moderate injury. Interestingly, only 6% of this sample dropped out of high school and 94% completed (i.e., GED, diploma). Employment was defined as any paid employment and post-secondary education was defined as engagement in any post-secondary program (e.g., 4-year college, community college,

transition program, apprenticeship). Significant predictors of those enrolled in post-secondary education included being female, later age at injury, and higher socioeconomic status. Significant predictors of those employed included higher socioeconomic status, not receiving rehabilitation, and higher injury severity. In addition to identifying several important predictors of productivity, this study is noteworthy as it utilized two models of productivity to independently predict both employment and post-secondary enrollment.

There is significant evidence supporting that a moderate to severe TBI during adolescence has the potential to significantly impact future productivity. Although still a developing literature base, the studies described above highlight several variables significantly associated with the productivity outcomes between one and eight years post-injury of employment and post-secondary engagement. Variables of consideration include injury severity (e.g., PTA), independent functioning, sex, transitional planning, behavioral sequelae, socioeconomic status, age at injury, and receipt of rehabilitation services. One variable not considered in the known literature on productivity after TBI but heavily researched in educational literature is high school exiting. This is a glaring gap in the literature and will be explored in this study.

Productivity after Adult Traumatic Brain Injury. In this section, the literature regarding TBI and future productivity will be discussed. Although there is minimal literature regarding productivity after TBI in adolescence, there is a much more developed literature base when examining adult or mixed-age samples, which overwhelmingly demonstrates that TBI has the potential to negatively impact future productivity (Taylor, Kreutzer, Demm, & Meade, 2003). In this section, the rate of productivity and variables significantly associated with productivity

will be discussed. Highlighted variables include race, sex, pre-injury problematic substance use, pre-injury productivity, injury severity, and functioning at rehabilitation discharge.

Gary, Arango-Lasprilla, and Stevens (2009) conducted a comprehensive literature review to determine if racial differences exist in post-injury outcomes after TBI (mild to severe). One of the post-injury outcomes examined was productivity (employment, education). To conduct their literature review, the researchers identified 39 peer-reviewed journal articles that included data on African Americans and Hispanics with TBI. Primary and secondary analyses were considered and outcomes included data from pediatric and adult samples and their caregivers. Out of the 39 studies identified, eight had employment or productivity outcomes. Out of the eight studies identified, seven found that racial minorities had greater difficulties with employment or productivity post-injury with time to outcome being one to five years post-injury. Racial differences in employment or productivity were found in regards to job stability and use of vocational support services. Similar findings were documented by Arango-Lasprilla and Kreutzer (2010) who reported that seven out of nine articles found racial minorities to have poorer employment between one and five years post-injury.

Soon after publishing their literature review on racial differences, Gary and colleagues (2009) published their own empirical study on the same topic examining employment one, two, and five years post-injury using a retrospective cohort design. Their study consisted of both White (n = 1,407) and Black (n = 615) participants with moderate and severe TBI. They defined productive as employed full- or part-time and defined nonproductive as unemployed, engaged in education, homemaking, volunteering, or retired. After controlling for a range of demographics (age, sex, pre-injury employment and education, marital status) and injury variables (PTA, GCS, admit and discharge functioning and disability, acute and rehabilitation length of stay, cause of

injury) they found that after a TBI, Black participants were more likely to be unemployed than White participants at all time points examined (1, 2, 5 years post-injury). Additionally, they found that age, discharge FIM (Functional Independence Measure) and DRS (Disability Rating Scale), length of stay (acute and rehabilitation), pre-injury employment, sex, education, marital status, and cause of injury were all predictive of employment post-injury. These findings are consistent with Kreutzer and colleagues' (2003) findings that racial minorities with a TBI were more likely to be unemployed than Whites with a TBI after controlling for age, injury severity, and disability. Overall, there is significant evidence that race plays a role in future productivity after TBI.

Sex is another demographic factor that appears to play a role in productivity after TBI (Gary et al., 2009). Corrigan and colleagues (2007) examined sex differences in employment one-year post-TBI. Their sample consisted of adults ($n = 3,444$) with moderate and severe TBIs. They did not include individuals that were below the age of 18, older than 64, a student, a homemaker, living in specialized housing, or retired and not working. Employment was defined as the difference between hours worked one-year post-injury to hours worked at the time of injury. The employment outcome was then categorized into four levels: increase in hours, the same number of hours, decrease in hours but still working, and decrease in hours and no longer working. Sex was found to be a significant factor in the change in productivity after TBI, controlling for age, race, education, marital status, insurance type, brain imaging, and length of stay. Compared to men, women were found to be more likely to decrease hours of employment or to stop working completely. Interestingly, women showed better employment as age increased and the sex difference was not found in the women aged 55 to 64-years-old. Although this well-conducted study found significant findings regarding sex and outcome, the literature overall is

largely mixed (Ownsworth & McKenna, 2004; Renner et al., 2012). There is some evidence showing that sex hormones during the childbearing years may play a role in differential effects (Bazarian, Blyth, Mookerjee, & McDermott, 2010). It is of note that previous studies on sex and TBI often have methodological issues due to sample disproportionality (more men than women; Kraus, Peek-Asa, & McArthur, 2000).

In addition to race and sex, there is substantial evidence that pre-injury substance use is negatively related to productivity post-TBI (Taylor et al., 2003). Sherer, Bergloff, High, and Nick (1999) investigated the contribution of post-injury functioning (e.g., physical, cognitive, behavioral) on productivity after accounting for injury severity, pre-injury education, and pre-injury substance use. The majority of participants ($n = 76$) were moderately (30%) or severely injured (55%) and the mean time to productivity follow-up was 22.5 (quartiles; 12.6, 20.7, 30.5) months post-injury and 12.9 (quartiles; 4.9, 12.4, 16.6) months post-discharge from treatment. Productivity was defined as employed or engaged in educational/vocational training. Although significant correlations were found between productivity and pre-injury education, functional supervision (physical, behavioral), and pre-injury substance abuse, only pre-injury substance abuse was found to be significant when all variables were entered in multiple logistic regression analysis. Additionally, when examining inter-quartile-range odds ratios of all predictors, participants scoring in the 75th percentile (higher pre-injury substance use) were 88% less likely to be productive than those in the 25th percentile.

In a similar study, Bogner, Corrigan, Mysiw, Clinchot and Fugate (2001) investigated the relative contribution of pre-injury substance abuse on future productivity. Participants ($n = 351$) in this study consisted of consecutive admissions to a TBI rehabilitation center, and productivity at one-year post-injury was defined as working, attending school, or volunteering. After

controlling for age, pre-injury employment, and FIM at discharge, pre-injury substance abuse was significant, with the total model accounting for 16% of the variance. The researchers concluded that pre-injury substance abuse was a strong predictor of productivity and further asserted that pre-injury substance abuse should be included in all studies of outcome after TBI. The two studies described above provide evidence supporting that pre-injury substance use significantly contributes to productivity after TBI.

Past behavior being indicative of future behavior is a popular mantra in the social sciences and is a principle heavily incorporated into the study of productivity after TBI. Given that there is a vast literature on the significance of pre-injury productivity (association and prediction), several of the previously mentioned studies included pre-injury productivity as a control in their modeling. In a study that sought to investigate the relationship between patient and acute injury characteristics on return to employment, pre-injury productivity was one of the primary variables of interest in modeling (Keyser-Marcus et al., 2002). Using a prospective longitudinal design consisting of 538 patients admitted to rehabilitation after a TBI, Keyser-Marcus and colleagues (2002) modeled employment at years one, two, three, four and five, post-injury by including the predictor variables of age, education, discharge DRS and FIM, rehabilitation length of stay, admission GCS, and pre-injury productivity. Pre-injury productivity and the outcome of productivity (i.e., return to work) were defined as competitively employed, employed in a sheltered workshop, or enrolled in school. When all variables were simultaneously entered into a multivariate logistical regression, pre-injury productivity was found significant at years one (OR = 5.13), two (OR = 3.53), three (OR = 3.63), and five (OR = 3.55). Age at injury was the only other variable that was statistically significant at more than one-time point, but the magnitude of its relationship was minimal (OR = .94 - .97). This study and other studies on

productivity after TBI provide evidence that pre-injury productivity is significantly associated with future productivity after TBI (Dikmen, Temkin, Machamer, Holubkov, Fraser, & Winn, 1994; Felmingham, Baguley, & Crooks, 2001; Sherer et al., 2002).

Injury severity is a variable that is included in virtually every empirical study regarding productivity after TBI. Post-traumatic amnesia (PTA) is one index of TBI severity that has an extensive literature base, which investigates its prediction of productivity post-TBI. PTA is best defined as the time from injury until the individual returns to orientation and can form and recall new memories with both its duration and severity influencing outcome (Nakase-Thompson, Sherer, Yablon, Nick, & Trzepacz, 2004; Nakase-Richardson, Yablon, & Sherer, 2007). Most studies indicate that PTA is more predictive of late outcome compared to the commonly used Glasgow Coma Scale (Sherer, Struchen, Yablon, Wange, & Nick, 2008).

Nakase-Richardson and colleagues (2011) conducted a study to validate a novel TBI severity classification model (Mississippi Intervals) that utilized PTA to predict productivity at one-year post injury and compared it to the widely used Russell Intervals (Russell & Smith, 1961). The Russell Intervals classify mild TBI as PTA less than 1 hour, moderate TBI as 1 to 24 hours, severe TBI as 1 to 7 days, and very severe TBI as greater than 7 days; the Mississippi intervals classify moderate TBI as 0 to 14 days, moderate-severe TBI as 15 to 28 days, severe TBI as 29 to 70 days, and extremely severe TBI as greater than 70 days. Participants (n = 3,846) in this study all suffered moderate to severe TBI by definition of being included in the TBIMS (Traumatic Brain Injury Model Systems) database. Productivity was defined as being employed part- or full-time, being enrolled in school part- or full-time, or being a full-time homemaker. When age, PTA, DRS at admission, GCS, and FIM at admission were entered into a multivariate logistical regression, PTA, age, and FIM were uniquely associated with productivity. When

compared to the Russell Intervals, the Mississippi Intervals were superior in predicting outcome and only slightly less predictive (nonsignificant) than total days in PTA. Duration of PTA has an extensive literature base regarding its utility in predicting outcome, including productivity. In this proposed study, the Mississippi Intervals will be used to describe the sample and duration of PTA will be used as an independent variable.

The last variable to be discussed in this literature review is functioning at discharge, as measured by the functional independence measure (FIM). The FIM, created by Keitll and colleagues (1987), is an indicator of patient disability that measures functional ability during rehabilitation and has been shown to have solid psychometric properties (reliability and validity) (Corrigan, Smith-Knapp, & Granger, 1997; Stineman et al., 1996). It is often administered upon hospital admission and discharge both to track progress and predict outcome for various populations, including individuals recovering from a TBI, stroke, cancer, and spinal cord injuries. Total scores on the FIM range between 18 and 126, with 18 signifying complete dependence in all domains and 126 indicating complete independence in all domains. The FIM covers 18 items that are summed to create a total score or can be split into cognitive and motor composites. Items include: eating, grooming, bathing, dressing upper body, dressing lower body, bladder management, bowel management, transfer from bed/wheelchair/chair, transfer from toilet, transfer from tub/shower, ability to walk/wheelchair, ability to uses stairs, communication comprehension, communication expression, social interaction, problem solving, and memory. Each of the 18 items is rated on a seven-point scale, see Table 1 below.

Table 1

Functional Independence Measure Item Responses

Score	Description
1	Total assistance with helper
2	Maximal assistance with helper
3	Moderate assistance with helper
4	Minimal assistance with helper
5	Supervision or setup with helper
6	Modified independence with no helper
7	Complete independence with no helper

There is extensive literature regarding the FIM and its association with future productivity after TBI (Hammond et al., 2001; Ownsworth & McKenna, 2003). Several studies previously described utilized it as a covariate to measure the unique association of the primary variable with the majority of studies finding the association between FIM and productivity significant (Bogner et al., 2001; Gary et al., 2009; Keyser-Marcus et al., 2002; Nakase-Richardson et al., 2011). In addition to the previously mentioned studies, in a seminal study conducted by Greenspan, Wrigley, Kresnow, Branche-Dorsey and Fine (1996) predictors of failure to return to work were examined for 343 participants aged 15 to 64 who were previously employed prior to their TBI with an special emphasis placed on functioning as measured by the FIM. At one-year post discharge individuals who did not return to work were far more likely to endorse levels of dependence or modified independence than individuals who returned to work. Interestingly, not graduating high school was also associated with failure to return to work at one-year post-discharge.

High School Exiting

High value is placed upon completion of secondary education in the United States and other post-industrial societies. When John King was the Secretary of Education at the U.S. Department of Education (2015), he famously stated that “A high school diploma is absolutely

critical, absolutely attainable, and key to future success in college, in the workforce and in life." In that statement, he powerfully emphasized the association between earning high school diploma and future productivity, both in terms of engagement in post-secondary education and gainful employment. Earning a high school diploma is seen as such a significant milestone that the U.S. Department of Education has invested more than \$1.5 billion in programming aimed at increasing graduation rates, improving achievement, and closing opportunity gaps through programs like Race to the Top, Investing in Innovation, School Improvement Grants, and expanding college access and affordability (U.S. Department of Education, 2015).

Graduating high school is viewed as a critical developmental milestone largely due to the evidence that successful exiting (i.e., diploma) is associated with a range of positive outcomes while unsuccessful exiting (i.e., dropout) leads to a higher chance of negative outcomes (Berkold, Geis, & Kaufman, 1998; Cameron & Heckman, 1991; Hull, 2009; Kienzel & Kena, 2006; Julian & Kominski, 2011; Wagner et al., 2005). In essence, high school exiting can be viewed as a pivotal developmental milestone in the transitioning from adolescence to adulthood. In the U.S., incomplete educational progression (i.e., dropout) has been associated with a wide range of negative adult outcomes including: poor mental health (Muntaner, Eaton, Miech, & O'Campo, 2004; Plies, Ward, & Lucas, 2010), poor physical well-being (Plies, Ward, & Lucas, 2010), limited social functioning (Lochner & Moretti, 2004; Freudenberg & Ruglis, 2007), and reduced economic productivity (Levin & Belfield, 2007; Renna, 2007; Rouse 2007).

Currently, it is believed that students, both with a TBI and without, are best served by graduating high school. However, this is an assumption when applied to students with a TBI and the same relationship may or may not exist when observed through empirical inquiry. It is possible that for a student with a serious TBI, factors known to influence productivity after TBI

(e.g., injury severity, functioning at discharge) account for the majority of the variance related to future productivity and high school exiting does not significantly contribute to productivity. Because of the current assumption, recommendations regarding high school exiting for students with a TBI have prematurely moved to the timing of diploma (on-time vs. delayed) rather than examining if earning a diploma improves outcomes. Currently, premature, contradicting, and nonevidence-based recommendations are being made based on timing of diploma. These premature recommendations can be found in the TBI literature including the Brain Injury Network (2008) and Semrud-Clikeman (2010) both of which advocate for students to delay graduation (often until the age of 21) while Todis and Glang (2008) found that school staff often advocate for an on-time graduation, citing the need for students to graduate with their peers and to avoid the stigma of staying in school longer. The timing of graduation may be important, but to answer that question we must first explore if high school exiting matters at all for this population.

Additionally, there are only limited data describing the rate of high school exiting and no data on students who attended neurorehabilitation. Furthermore, there are no data regarding differences between exiting group. These foundational data are glaringly absent from the literature. Lack of foundation descriptive data and examining if exiting type is related to outcome (e.g., productivity) are the aims of this study. In this section, the types of high school exiting will be discussed (primary, alternative), their rates, and the literature regarding relationships to future productivity will be explored.

High School Exiting Types. The three main types of high school exiting to be discussed in this section and utilized in this study include high school diploma, GED, and dropping out. It is important to note that there often are alternative diploma options available to students

including diplomas or certificates that reflect high academic achievement and others specifically for students receiving special education services (Guy, Shin, Lee, & Thurlow, 2000; Martinez & Bray, 2002). The availability and requirements to achieve these alternative degrees vary greatly between states. Johnson and colleagues (2007) found that some states (including the District of Columbia) had up to five diploma or certificate options while 21 states only had a high school diploma option. Johnson, Thurlow, and Schuelka (2012) surveyed all 50 states plus the District of Columbia and found that for students with a disability, 100% of states offered a regular diploma, 37% certificate of attendance, 29% certificate of achievement, 25% honors diploma, 22% special education diploma, 6% occupational diploma, and 16% offered a state specific certificate or diploma. Some states only offer nonhonors alternative diplomas/certificates (e.g., special education diploma, certificate of attendance, certificate of achievement, vocational diploma) to students with disabilities while others make these options available to nondisabled students as well. Little is known about the usefulness of alternative certificates or diplomas, and they may or may not be useful in helping a student enter post-secondary education and/or employment (Department of Labor, 2009).

In this study, the three types of exiting available across all states (i.e., dropout, GED, diploma) will be explored as there is significant evidence that a hierarchy exists across a range of outcomes (Ou, 2008). A high school diploma is awarded after successful completion of high school requirements (Johnson, Thurlow, & Schuelka, 2012). Requirements may include a minimum level of achievement, total credits earned, passing a state exit exam, or using the SAT or ACT in place of a state exit exam (Johnson, Thurlow, & Schuelka, 2012). Additionally, most states (96%) make allowances for students with disabilities so they may receive a standard diploma. These allowances may include reducing the total number of credits required (6%),

optional courses (45%), lowering performance criteria (18%), utilizing the IEP to set graduation requirements (71%), and granting of extensions (29%). Johnson, Thurlow, and Schuelka (2012) found that for students with a disability, most states (88%) provide minimum requirements and allow local educational agencies (LEA) to add to them, 8% provide minimum requirements and do not allow them to be adjusted, and one state (Wisconsin) provides guidelines but allows LEAs to set up requirements. The Districts of Columbia provides no guidelines or requirements and leaves it completely up to the LEAs. Requirements appear to be increasing overall with 66% of states reporting an increase in diploma requirements both for students with and without disabilities between 2003 and 2011.

The second high school exiting type is earning a GED through passing the Test of General Educational Development. The technical name of the award achieved is the Certificate of High School Equivalency although it is commonly referred to as the GED. In this document the term GED will be used rather than the Certificate of High School Equivalency. The exam passed to earn a GED tests knowledge in five domains: math, reading, science, social studies, and writing. The purpose of the GED is to certify that its recipients have the equivalent skills and knowledge to those who graduate with a traditional high school diploma (Heckman, Humphries, & Mader, 2010). The GED is accepted by most universities and colleges as an alternative to the high school diploma and most companies that require a high school diploma often accept the GED (Chapman, Laird, & KewalRamani, 2012). Although the GED is a useful alternative to the diploma, those with a GED tend to fare significantly worse than students with a diploma (Chapman, Laird, & KewalRamani, 2012). The third type of exiting included in this study is dropping out. Students are defined as dropping out if they exit high school without a diploma or

fail to earn a GED. These students do the worst out of these three groups across a range of outcomes.

High School Exiting Rates. Rates of high school exiting (dropout, GED, diploma) are key educational and economic benchmarks. Murnane (2013) examined U.S. high school graduation rates (i.e., exiting with diploma) over time and found three major trends. It is important to note that these data reported are not four-year graduation rates, but are rather exiting rates for individuals aged 20 to 24 which are similar to the rate to be explored in this study. The first trend found was that between 1970 and 2000 overall growth in graduation rates were largely stagnant and slightly decreased over time (80.8% vs. 77.6%). Secondly, between 2000 and 2010 there was a significant increase in high school graduation rates overall (77.6% vs. 83.7%) and most prominently among Blacks (68.0% vs. 78.2%) and Hispanics (63.9% vs. 77.8%). Thirdly, gaps in graduation rates are consistently found when examining race, income, and gender. Murnane's analysis of the data is that the stagnation between 1970 and 2000 was caused by increasing non-monetary cost (e.g., time, increased requirements) associated with high school completion and the growing availability of the GED option. He further states that although there are several hypotheses regarding the overall jump in rates from 2000 (77.6%) to 2010 (83.7%) the cause of this increase is yet to be explained empirically.

Other studies have also examined the long-term trends in U.S. graduation rates (i.e., exiting rates). Hull (2009) utilized a longitudinal cohort consisting of all high school freshman in the U.S. in 1988 and found that 83.5% of students graduated in four years and an additional 3.7% graduated within eight years (87.4% overall diploma rate), 5.4% attained a GED, and 7.4% dropped out. In a similar study, Chapman and colleagues (2011) utilized longitudinal population data from 1972 to 2009 to examine trends in U.S. high school exiting over time. They found that

the rate of total graduation steadily increased from a low of 82.9% in 1972 to near high of 89.8% in 2009. In terms of dropouts, rates decreased from a high of 14.6% in 1972 to a near low of 8.1% in 2009. This study did not describe the trend in GED attainment rate.

Perhaps the most complete and current data on high school exiting were contained in a report conducted by the U.S. Department of Education (Chapman, Laird, & KewalRamai, 2011). In this report they examined overall trends in high school completion (combined GED and diploma) and dropout between 1972 and 2009. They found that students between the ages of 16 through 24 dropped out (no GED or diploma) at a rate of ~15% in 1972 that steadily declined to a rate of ~8% in 2009. Significant racial disparities were found in terms of race, sex, and family income. When examining completers over time they did not separate out those who earned a GED and those who earned a diploma. Rates of completion from 1972 to 2009 increase from ~82% to ~90% again with disparities found in terms of race, sex, and family income. In 2009 ~85% of students exited with a diploma while ~5% earned a GED. Although progress has been made in decreasing dropout rate among all income groups, disparities still exist in terms of race, sex, and family income. Overall, these data suggest that among the U.S. student population from 1970 to 2010, the diploma rate has increased from ~80% to ~90%, GED rates are ~5%, and dropouts have decreased from ~15% to ~8%.

High School Exiting Rates for Student in Special Education. High school exiting type is important for students in general education and special education. The U.S. Department of Education (Chapman, Laird, & KewalRamai, 2011) found that in 2009 nondisabled high school students completed high school (diploma, GED) at a rate of 90% while only 80% of students with a disability completed high school. In terms of dropouts, in 2009 7.8% of nondisabled students dropped out compared to 15.5% of students with disabilities. In this study disability was

defined as any student who reported issues relating to hearing, vision, walking or climbing stairs, dressing or bathing, doing errands alone, concentrating, remembering, or making decisions.

In a similar study, Wagner and colleagues (2005) used the National Longitudinal Transition Study – 2 to examine the postschool transitioning for roughly 11,000 cross-categorical special education students two years after high school exiting. Although outcome after high school was the primary focus of this study, high school exiting was commented on descriptively. Overall, 68% of youth with disabilities graduated with a diploma, 4% exited with a GED, and 28% dropped out. Students with emotion disabilities had the lowest level of high school completion at 56% while students with a TBI completed at a rate of 79%. It is of note that out of the 79% of completers with a TBI, 94% graduated with a regular high school diploma. Compared to the 12 other special educational categorized, students with a TBI had the 5th best completion rate. It is important to note that these students in this study were simply qualified under special education for TBI, it is unknown if they attended neurorehabilitation or group differences between those with a TBI who graduated or dropped out.

Description of exiting rates for students in special education can also be found in the raw data compiled by The National Center for Educational Statistics (NCES). The NCES compiles data on the type of high school exiting for both the general population of students as well as students receiving special education. The most recent exiting data from NCES for the 2013-2014 school year indicates that out of the 2616 students exiting high school and qualified for special education service under TBI, 12.19% dropped out, 14.53% earned a GED, and 69.23% graduated with a high school diploma. An additional 3.21% of students qualified for special education under TBI aged out of the education system which is the equivalent of dropping out, raising the true dropout rate to 15.4%. Among all students with an IEP (N = 391,785), 18.47% dropped out,

13.54% GED, 66.12% diploma, while 1.52% aged out (19.99% true dropout rate). Overall, students with a disability appear to dropout at high rates and earn a diploma at lower rates than the general student population.

High School Exiting Rates for Students with Traumatic Brain Injury. Describing the rate of exiting and group differences for adolescents with a moderate or severe TBI who attend neurorehabilitation are aim one of this current study. Currently there are no data on this population in terms of rates of exiting nor any data on differences between exiting groups (e.g., injury severity, sex, functioning at discharge, urbanity, mechanism of injury, length of stay, insurance type). Data looking at both rate and group differences has the potential to assist professionals in communicating what is normative exiting and the formulation of nuanced predictions based on risk factors and protective factors. This basic information can then be used to guide clinical care, transitioning, and the communication of realistic expectations to the injured, their families, schools, and other stakeholders. These data also could inform future research and policy. The data on high school exiting for students with TBI are so lacking that outside of Wagner (2005) and the NCES data there are only two known TBI studies that mention the rates of exiting with neither focusing on this potentially important rate nor describing group difference.

Kriel and colleagues (1988) described the rate of high school exiting as part of their study examining adolescents transitioning to adulthood after severe head injury. This study had significant methodological limitation (large attrition rate, small sample size) but is noteworthy for being the first to explore the exiting of students with severe TBI. In this study the researchers surveyed 29 out of 97 former patients who experiences a severe TBI between the ages of 13 and 18 years old and when they were 18 to 27 years old and transitioning to adulthood. They found

that only 64.3% of students had graduated with a diploma or special education certificate and that 28.6% had dropped out of high school. GED was not reported on and 7.1% were still in high school upon follow-up. Using a population reference group they found that there was a statistically significant difference for youth with TBI and youth without both in terms of dropouts (28.6% vs. 9%) and diploma (64.3% vs. 82.9%) rates. Rates of those still in high school were the same. This study had significant flaws including a small sample size ($n = 29$) and sample bias.

Todis and colleagues' (2011) described the rate of high school completion in their longitudinal study on post-high school transitioning for adolescents with TBI. Participants ($n = 89$) in this study had a mean age of 12.01 at injury ($SD = 6.30$) and were between 18 and 22 years old at the start of recruitment with follow-up data collected every six months for five years. By the end of the final follow-up, 94.4% of participants had completed high school with only 5.6% reported to have dropped out. A significant limitation to interpreting this rate is that it is likely several of the participants in this study were injured after high school exiting as the range for age at injury was 0.05 to 20.24 years old. Overall, the known studies focusing on adolescent TBI that describe the rates of exiting have methodological limitations (Kriel et al., 1988; Todis et al., 2011) with none focusing specifically on adolescents or adolescents exiting inpatient neurorehabilitation prior to high school exiting. The best current data describing the rate of exiting after TBI are findings from studies exploring rates across disability categories (Wagner et al., 2005) and these are superficial at best. Furthermore, there is not one known study that's primary focus is to describing the rate of exiting after TBI or describing differences across exiting groups.

High School Exiting and Productivity. High school exiting is an important social and developmental milestone for the general student population (Chapman, Laird, & KawalRamani, 2011; Ou, 2008; Wagner et al., 2005) and is assumed to be for those who have suffered a TBI (Todis & Glang, 2008). There is significant literature supporting that a hierarchy exists across exiting types (i.e., diploma, GED, dropout) across a range of important adulthood outcomes including productivity (Berkold, Geis, & Kaufman, 1998; Cameron & Heckman, 1991; Hull, 2009; Kienzel & Kena, 2006; Julian & Kominski, 2011; Wagner et al., 2005). Vocational and educational indices of adult productivity are two of the primary outcomes explored in the high school exiting literature. Productivity is often defined operationalized categorically, being gainfully employed or not, and being enrolled in postsecondary education or not. Occasionally, these indices are broken down into more discrete metrics, which include level of employment/education (part vs. full), annual income, per-hour pay, utilization of social services, or degree completion.

The literature on high school exiting indicates that an exiting hierarchy exists in relation to adulthood productivity for the general student population with limited evidence regarding those with a disability. Generally, students who graduate with a diploma have the highest likelihood of being productive, followed by those who attain a GED, and the least productive being students who drop out of high school (Ou, 2008). In terms of the general student population, Julian and Kominiski used data (2011) from the U.S. Census Bureau and found that the median earnings of high school dropouts are 49% less per year than the median earnings of high school completers. After controlling for level of employment, there was still a 20% difference between dropouts and completers. These population level findings are evidence that high school dropouts earn less and that they earn less per unit of vocational engagement. Rouse

(2007) projected these earnings differences over an individual's lifetime and found that the average high school dropout earns \$630,000 less than those who completed high school over their lifetime. Additionally, individuals who dropped out of high school were less likely to be employed than those who completed high school.

Levin and Belfield (2007) examined the macroeconomic impact of high school dropouts on the U.S. economy and found that dropouts cost the U.S. economy roughly \$240,000 more than high school completers due to their lower tax contribution, higher use of Medicaid and Medicare, higher reliance on other welfare services, and cost due to criminal activity. In terms of enrollment in postsecondary education, Berkold, Geis, and Kaufman (1998) found that only 8% of high school dropouts attended two or four-year college compared to 57% of high school completers. In this study, they also found that high school dropouts were much more likely to be looking for work (16%) than those who completed high school (6%). These studies demonstrate the significant difference in adult productivity associated with earning a diploma compared to dropping out of high school.

Cameron and Heckman (1991) compared those who earned a GED to those who dropped out of high school and found that they are both similar in terms of wages, total earnings, hours of work per week, unemployment, and job tenure. Interestingly, these findings remained stable after controlling for level of ability. Cameron and Heckman came to the conclusion that the only advantage of a GED over drop out is that the GED may allow an opening for post-secondary schooling and other training opportunities. The conclusion of a GED opening the door for post-secondary education was supported by findings from the U.S. Census Bureau (2008), which reported that 42.8% of students with a GED attained some college credit. However, that was still significantly lower than those who graduated with a diploma with 72.8% earning college credit.

Additionally, the U.S. Census Bureau (2012) found that students with a GED on average earned \$3,149 per month while high school graduates earned \$4,690 per month. A limitation of this study is it did not compare GED earners to dropouts. In general, among the general student population individuals who attained a GED are equal to or slightly more productive than students who drop out but less productive than students who graduate high school with a diploma.

There is surprisingly little data regarding the relationship between high school exiting and productivity among students with a disability (Thurlow & Johnson, 2011). The only known study that examines the impact of diploma vs. dropout is the previously mentioned study by Wager and colleges (2005) which utilizes the National Longitudinal Transition Study-2 (NLTS-2) and it is almost universally cited when discussing this topic. When revisiting the Wager data and examining productivity of all students with a disability, rather than only students with a TBI as previously discussed, they found that only 69% of high school dropouts were engaged in school, work, or preparation for work shortly after high school exiting which was significantly less than the rate of 86% reported by high school completers (i.e, GED, diploma). After controlling for differences between completers and dropouts (e.g., functional cognitive abilities, previous academic achievement), dropouts were 18% less likely to be enrolled in a college (two or four year) than completers with only 8% of dropouts having attended technical, business or vocational schools and only 1% having attended a two-year college at some point after high school exiting. By comparison, 5% of high school completers attended technical, business, or vocational schools and 27% attended a two-year college. When multivariate analyses were conducted, higher functional cognitive skills, being female, head of household education, progressing to the next grade level each year in school, and graduating from high school were associated with post-secondary education across disability categories. Overall, there is significant evidence that high

school exiting is associated with productivity in the general student population and limited evidence among youth with a disability including those with a TBI.

Literature Summary

Traumatic brain injury is a serious injury that may result in a wide range of impairments. These impairments can significantly disrupt the attainment of meaningful developmental milestones including high school exiting and adulthood productivity. Injured adolescents may participate in neurorehabilitation to regain lost skills and functioning, accommodate to new limitations, and to prepare for a productive adulthood. Currently, there is a sizable evidence base regarding factors associated with productivity after TBI in adulthood and a limited evidence base for this same association in terms of adolescents with a TBI. Domains of factors associated with productivity include demographics, pre-injury functioning, injury severity, and functioning at medical discharge. Additionally, there is significant evidence that high school exiting type is associated with adulthood productivity for students in the general population and limited evidence of this relationship for students with a disability. A gap in the literature exists regarding the description of exiting rates (aim one) and the association between high school exiting and future productivity for students with a TBI (aim two). Aim one and aim two of this study will provide preliminary evidence addressing these two gaps in the literature and have the potential to inform future research, clinical practice, policy.

Chapter 3: Method

The purpose of this study was to explore the intersection of moderate and severe traumatic brain injury and high school exiting type (i.e., diploma, GED, dropout) for adolescents who attended inpatient neurorehabilitation prior to high school exiting. The first aim of this study was to describe the rates at which these injured adolescents exit high school by dropout, GED, or diploma, and to explore differences between these three groups (e.g., race, insurance type, injury severity). There are no known data on these rates or group differences for this population. The second aim of this study was to explore if high school exiting type is uniquely associated with future productivity for this population. For students with a serious brain injury it is currently assumed that high school exiting is related to future productivity, but this is almost entirely based on data from uninjured students. It is possible that this assumption does not hold for this unique population as other factors (e.g., injury severity, pre-injury functioning, functioning at discharge) may play a more prominent role in the prediction of future productivity.

To achieve the first aim of this study, the rates of high school exiting were described, and comparative analyses (*t*-test, chi-square) were utilized to examine differences between students who dropped out, earned a GED, or graduated high school with a diploma, across a range of variables. In these descriptive and comparative analyses, the variables explored were both those with established literature relating them to future productivity after TBI (e.g., demographics, pre-injury functioning, injury severity, functioning at discharge) and those central to description (e.g., urbanicity, insurance type, length of stay, mechanism of injury, hours of productivity).

The second aim of this study explored if a unique relationship exists between exiting type and future productivity. This is the first step in understanding if high school exiting type matters for students with a TBI and builds off of the foundational description provided by aim one. To examine if a relationship exists a set of three multiple regressions analyses were utilized with nesting accounted for (i.e., students were nested within rehabilitation centers). Variables utilized in analyses included a priori variables based on the TBI and productivity literature. Additionally, analyses were conducted on sample attrition to determine if covariates were needed to account for potential sampling bias.

Final variable selection was based on sampling differences, missingness, variability, and variable interrelatedness. A priori control variables included demographics (i.e., race, sex), pre-injury functioning, (i.e., problematic substance use, special education, learning problems, working problems), injury severity (i.e., days of post-traumatic amnesia), functioning at discharge (i.e., functional independence total score), and confounds considered included insurance type, urbanicity, mechanism of injury (e.g., motor vehicle collision, assault, fall), and length of stay (i.e., acute, rehabilitation). In addition to the control variables (a priori and potential counfounds), the variable of interest was high school exiting type. A unique relationship was identified if diploma and/or GED was significant above the referent groups of dropout after statistical control. The outcome of productivity was examined in three ways, hours spent in employment per week, hours spent in post-secondary education per week, and total productivity (sum of weekly hours in employment and post-secondary education). It is important to note that the outcome of total productivity is not independent from the other two outcomes since it is a sum of the employment and education outcomes. The five research questions asked in this study are as follows:

Research Question 1

What are the rates of high school exiting (e.g., diploma, GED, dropout) for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

Research Question 2

Do exiting groups differ across descriptive variables and variables related to productivity (demographics, pre-injury functioning, injury severity, functioning at discharge) for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

Research Question 3

What is the unique relationship between high school exiting type and total weekly hours productive (i.e., hours engaged in post-secondary education and employment) at 5-years post-injury for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

Research Question 4

What is the unique relationship between high school exiting type and total weekly hours engaged in employment at 5-years post-injury for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

Research Question 5

What is the unique relationship between high school exiting type and total weekly hours engaged in postsecondary education at 5-years post-injury for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

Participants

Participants in this study were part of the Traumatic Brain Injury Model Systems (TBIMS) database. Participants in this study were adolescents aged 16 to 18 years who suffered a moderate or severe brain injury while in high school. The study-specific inclusion criteria listed below were created to isolate the sample of interest from the greater TBIMS dataset.

Data Source – Traumatic Brain Injury Model Systems Database. The TBIMS is a coordinated system care with its funding supporting scientific inquiry to increase rehabilitation outcomes after TBI. It is funded by the U.S. Department of Health and Human Services through the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR). The TBIMS is one of three Model Systems programs sponsored by NIDILRR. The other two Model Systems are the Spinal Cord Injury Model Systems and the Burn Injury Model Systems.

The TBIMS was established in 1987 with the mission of conducting research that contributes to rehabilitation intervention as well as clinical and practice guidelines that improve the lives of brain injury survivors. There are currently 16 TBIMS centers along with three follow-up centers located across the U.S. (see Figure 1; National Institute on Disability, Independent Living, and Rehabilitation Research, 2016). Centers are required to have four components: emergency medical services (Trauma level 1), acute neurosurgical care, comprehensive inpatient rehabilitation, and long-term interdisciplinary follow-up and rehabilitation services. Participants included in the TBIMS database need to meet five criteria including: suffered a moderate to severe TBI, admitted to emergency department within 72 hours of injury, 16 years of age or older, received both acute and inpatient rehabilitation care within model system hospitals, and informed consent signed by patient, family, or guardian. Variables

collected as part of the TBIMS protocol include demographic information, pre-injury characteristics, injury characteristics, rehabilitation factors, post-rehabilitation morbidity and various outcomes (e.g., productivity, marital status, education, living status, disability). Baseline data are collected during neurorehabilitation stay (admission to discharge) through participant self-report, record review, and proxy report if needed. Follow-ups occur at years one, two, and five years post-injury and then continue at five-year intervals (e.g., 10, 15, 20). Follow-ups utilize participant self-report or proxy report either in person, over the phone, or through a mailed out packet. The one-year follow-up has a four-month window, the two-year follow-up has a six months window, and the subsequent follow-ups (5, 10, 15, 20, etc.) have a 12-months follow-up windows. Follow-up dates are based on years from injury and follow-up windows are split before and after the anniversary. For example, for the one-year follow-up, the follow-up due date is 12 months from injury, and the window is two months before the one-year anniversary to two months after the anniversary. For the five-year follow-up, the due date is 60 months from the injury with the window being between 54 and 66 months post-injury. Researchers access these data through the formal data request procedures available through the TBIMS National Data and Statistical Center.

To maintain data quality, data collected through the TBIMS go through extensive standardized procedures in terms of data documentation, data collection, data processing, security, and overall research operations. In terms of documentation, the data collected at baseline are called Form One. Form One data forms include: coversheet, medical record abstraction form, pre-injury history interview form, pre-injury questionnaire (English and Spanish), neuropsychological battery, CT data, and the Disability Rating Scale (DRS). The follow-up data collection procedures are called Form Two. Form Two data forms include the

data collection form (English and Spanish) and the data collection mailout form (English and Spanish). To further maintain data quality there is a uniformed data quality guidelines form. This form includes guidelines for the FIM, DRS, pre-injury history data, intracranial CT diagnosis, data collected from medical charts, Form One certification, data entry, data error discovery, data collected by interview, coding consistency, missing data reports, enrollment reports, Form Two overdue directions, quarterly reports, best practices for follow-up, and data quality targets.

Data collection procedures are standardized through universal documentation describing the guidelines for identification of subjects, guidelines and strategies for recruitment and consenting, information on sampling for national database enrollment, instructions for pre-injury history questionnaire, guidelines and strategies for maximizing follow-ups, guidelines for collection of follow-up data, data quality guidelines, information on how to handle unexpected events at follow-up, and information regarding the entering of enrollment data. Data processing is standardized by documented procedures for quarterly data submissions, editing, entering and submitting old data, obtaining information regarding participant cause of death, and data security. Overall TBIMS operations are standardized through documented procedures regarding the data use agreement, request for data (internal and external), resolving data collection and coding questions, implementing database changes, collaborative relationships, modules, special interest groups, performance target monitoring, branding and authorship policy, process to nominate committee leadership, and information regarding adding affiliate hospitals to the TBIMS's network of care. All of these policies are designed to promote data quality, data security, and to allow the TBIMS to meet its overall research mission of conducting state of the art brain injury research and can be found at <https://www.tbindsc.org/SOP.aspx>.

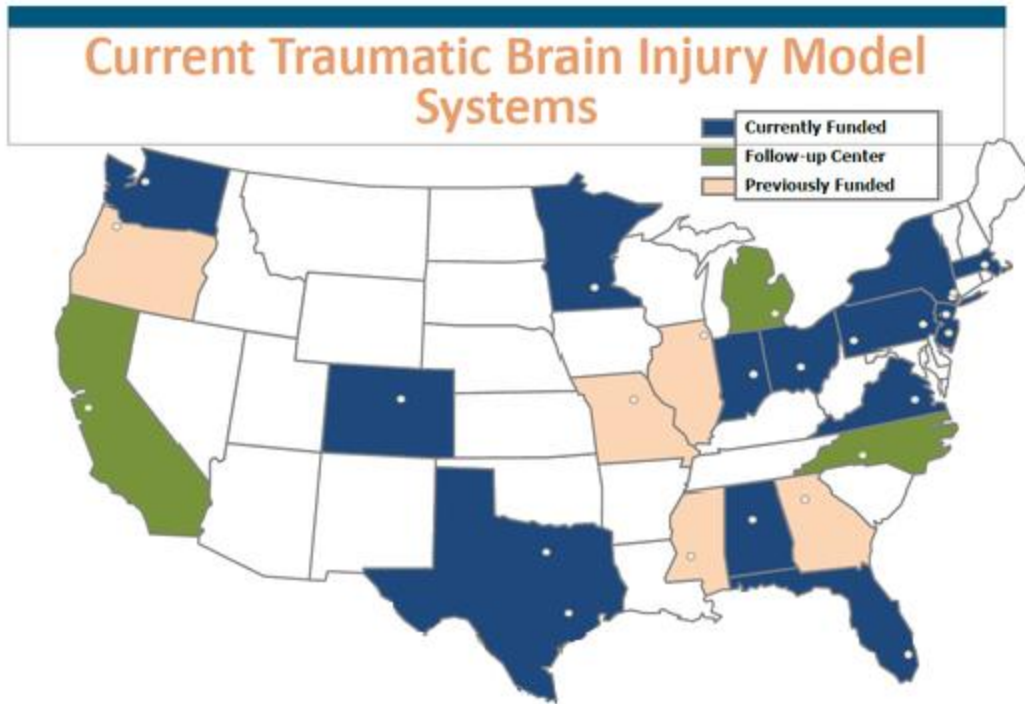


Figure 1. Map of TBIMS Center Locations

Inclusion/Exclusion Criteria and Justification. This study had two sets of inclusion and exclusion criteria. The first set was based on the criteria set by NIDILRR for their TBIMS database that was described in the previous section. The second set of criteria was created for this study. A flow diagram (Figure 2) was created to depict follow-up attrition for this study.

Traumatic Brain Injury Model Systems Inclusion Criteria.

- 1) Participants must have been at least 16 years of age at injury.
- 2) Participants must have suffered a moderate to severe brain injury. TBIMS defines moderate to severe TBI as damage to brain tissue by an external mechanical force as evidenced by either abnormal intracranial neuroimaging, post-traumatic amnesia greater than 24 hours, loss of consciousness exceeding 30 minutes, or Glasgow Coma Scale less than 13 (unless due to intubation, sedation, or intoxication).

- 3) Participants must have been admitted to the emergency department within 72 hours of injury.
- 4) Participants must have received both acute and inpatient rehabilitation care within model system hospitals.
- 5) Informed consent must have been signed by the patient, family, or guardian.

Study Specific Inclusion/Exclusion Criteria.

- 1) Participants must be at least 16 years of age and no older than 18 years of age at injury.
 - Justification – Participants must have been typically-aged high school students at injury.
 - TBIMS variable used – AGE
 - AGE was collected as part of the form one medical record abstraction form.
- 2) Participants must have been full-time high school students at the time of injury. Full-time high school status was based on self or proxy-report of educational engagement prior to injury.
 - Justification - Participants must have been typically matriculating (e.g., not part-time) through high school at injury
 - TBIMS variables used – EMP1, EMP2, EMPLOYMENT, EDUCATION, GED, EduYears
 - EMP1, EMP2, EDUCATION, and GED, and EduYears were collected as part of the form one pre-injury history interview.

- EMPLOYMENT was a computed variable and combines EMP1 with the archived variable Emp1Old from the form one pre-injury history interview.
- 3) Participants must have 5-year productivity outcome data and not in special education at 5-year post-injury.
- Justification – Primary outcome measure.
 - TBIMS variables used – IntStatus.5, PRTWork.5, PRTSchool.5, EMPLOYMENTF.5
 - IntStatus.5, PRTWork.5, and PRTSchool.5 were collected as part of the form two data collection form.

Overall, the process of isolating the sample of interest, full-time high school students at time of injury with five-year outcome data, was conducted through the following procedure. First, it needed to be determined that participants were ages 16 to 18 years at the time of injury. This was done by excluding all participants indicated as over the age of 18 years by the TBIMS AGE variable. Secondly, it needed to be determined that all students were full-time students at injury. This was indicated by being coded as a full-time student by the TBIMS variables of EMP1, EMP2, or EMPLOYMENT. Any participants not coded as full-time across these three variables were excluded. Thirdly, the TBIMS variables of EDUCATION, GED, and EduYears, were used to determine if participants, already known to be full-time students, were full-time high school students at injury. They were coded as high school students if across these three variables they had passed at least 8th grade, had not exited with a GED, had not exited with a diploma, and had not attended college. Lastly, to determine if all participants had the outcome of interest, the TBIMS variables of IntStatus.5, PRTWork.5, and PRTSchool.5, was examined.

IntStatus.5 indicated if they were successfully followed and the completion PRTWork.5 and PRTSchool.5 indicated the presence of outcome data. Because the productivity outcomes of interest (i.e., PRTWork.5, and PRTSchool.5) were adopted by TBIMS on 10/1/07, all participants in the study incurred their injury between 4/1/2003 and 10/1/2010. These dates were selected as all participants injured in this time period were eligible to report on this variable during their five-year follow-up after accounting for the follow-up window. The flow diagram (see Figure 2) graphically depicts the reasons (e.g., withdrawn, expired, incarcerated) participants who were full-time high school students between the ages of 16 and 18 years at injury did not have outcome data and were therefore excluded from the primary aim one and aim two analyses.

Variables

Several variables were used in this study to describe the sample and to conduct analyses. When variables were created (e.g., exiting type, productivity) their construction was described below. When established TBIMS variables were used directly their source was identified and their properties discussed. All variables were included in description (research question one) and exiting group comparisons (research question two).

High School Exiting Type. This variable was used descriptively to answer research question one and two and was the independent variable of interest for research questions three, four, and five. The purpose of this variable was to categories how students exited high school. To do this the TBIMS calculated variable of EDUCATIONF.5 was used. This variable was calculated through a crosswalk between the current five-year education variable of FEducationYears and the archived five-year education variable of Fschool (used prior to 2010). The wording of the current variable (FEducationYears) had the interviewer (or mail home

packet) ask the patient “How many years of education have you completed?” with responses including: 1 year or less, 2 years, 3 years, 4 years, 5 years, 6 years, 7 years, 8 years, 9 years, 10 years, 11 or 12 year with no diploma, HS diploma, work toward associate’s, associate’s degree, work toward bachelor’s, work toward master’s, master’s degree, work toward doctoral level, doctoral level degree, other, unknown.

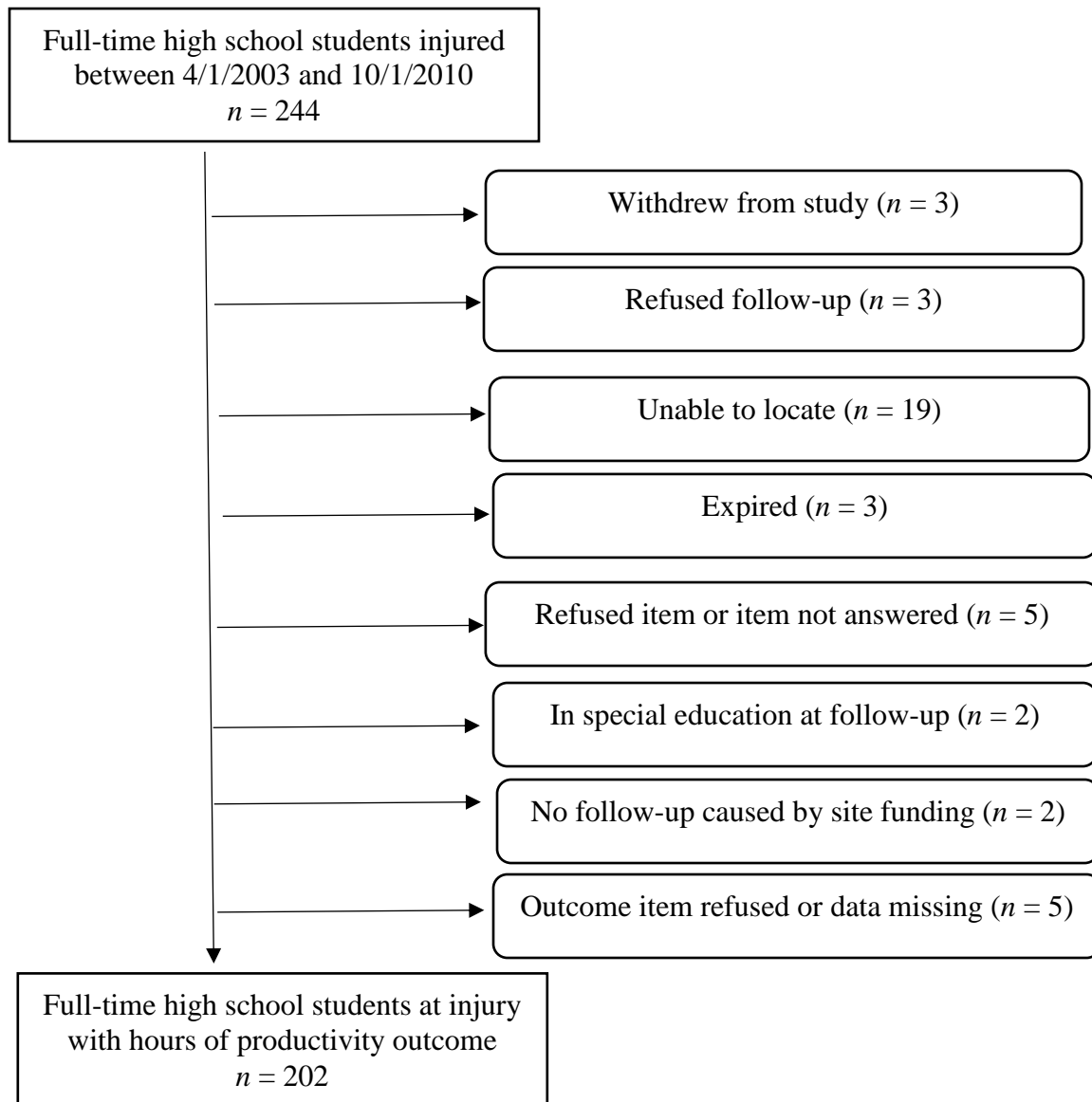


Figure 2. Flow Diagram

After implementing the crosswalk that combined the current variable FEducationYears and the prior variable of Fschool, the calculated variable of EDUCATIONF.5 was coded as 8th grade or less, 9 – 11th grade, GED, HS/GED, HS, Trade, Some College, Associate, Bachelors, Masters, Doctorate, Other, and Unknown. Due to the study constraints described above, only full time students who had passed 8th grade and not exited via GED or diploma were included in this study. Participants coded as in college were assume to have earned either a GED or diploma.

Outcome Variables – Productivity. Three outcome variables were used to model productivity five years after adolescent TBI. The TBIMS variables of PRTWork and PRTSchool were used independently as the outcomes for research questions four and five, respectively, and were summed for the outcome for research question three. Both of these variables came from the Participation Assessment with Recombined Tools Objective - 17 (PART-O) which was utilized during all follow-ups. The purpose of the PART-O was to measure participation for people with disabilities in life situations. The items of PRTWork and PRTSchool measure hours of weekly engagement in employment and education. The PRTWork item was worded as “In a typical week, how many hours do you spend working for money, whether in a job or self-employed?” and PRTSchool was worded as “In a typical week, how many hours do you spend in school working toward a degree or in an accredited technical training program, including hours in class and studying?”

Within the TBIMS the responses to these variables were reported categorically and were recoded into an ordinal dependent variable. The original categorical range was recoded by taking the median of the range (see Table 2). Because the final category (35 hours or more) did not have a range, it was simply recoded as 35 hours.

Table 2

Recoding of Hours Productive

Original Hours Range	Recode
0	0
1-4	2.5
5-9	7
10-19	15.5
20-34	27.5
35 or more	35

Statistical Control Variables. Statistical control was used to answer research questions three, four, and five through multiple regression analyses. The a priori control variables were theory driven and included demographics, pre-injury functioning, injury severity, and functioning at inpatient neurorehabilitation discharge. A priori variables included sex, race, pre-injury problematic substance use, pre-injury learning problems, pre-injury working problems, pre-injury special education, days of post-traumatic amnesia, total functioning score at discharge. Additional variables used in description also were considered as potential confounds (insurance type, urbanicity, acute length of stay, rehabilitation length of stay, mechanism of injury).

All control variables were taken from TBIMS form one (e.g., baseline) and included variables from pre-injury to discharge from rehabilitation. All of these variables were collected through patient interview, record review, and proxy interview if needed. The pre-injury demographic (race, sex) and pre-injury functioning items (learning problem, working problems, substance use, special education) were originally from the U.S. Census and were adapted for the TBIMS.

Sex. These data were collected from medical abstraction under the TBIMS variable SEX. The sex of the participant was coded as male or female. If transsexual it was coded as the

person's current sex. Male was used as the referent group in analyses. This a priori control variable was ultimately used in the regression analyses.

Race. These data were collected from the pre-injury interview under the variable RACE. The item wording was, "What is your race?" TBIMS categories for the variable included White, Black, Asian/Pacific Islander, Native American, Hispanic, Other, and Unknown. Hispanic is technically an ethnicity but is often coded as race as in the TBIMS. Because of low cell counts, this study coded the four most prevalent races in the sample (White, Black, Hispanic), with the other races combined to form Other Race (Asian/Pacific Islander, Native American, Other). This a priori control variable was ultimately used in the regression analyses with the race of White as the referent group.

Problematic Pre-injury Substance Use. These data were collected from the pre-injury interview under the variable PROBLEMUse. The series of questions asked included, "During the year before the injury, did you use any illicit or non-prescription drugs", "During the month before the injury, how many days per week or per month did you drink any alcoholic beverages, on the average", "A drink is 1 can or bottle of beer, 1 glass of wine, 1 can or bottle of wine cooler, 1 cocktail, or 1 shot of liquor. On the days when you drank, about how many drinks did you drink on the average", "Considering all types of alcoholic beverages, how many times during the month before the injury did you have five (four for females) or more drinks on an occasion?" Coded positive if participant engaged in binge drinking of alcohol (5 or more drinks on occasion), heavy drinking of alcohol (14 drinks a week for male or 7 drinks per week by a female), or use of illegal drugs. This a priori control variable was ultimately used in the regression analyses.

Pre-injury Special Education. These data were collected from the pre-injury interview under the variable SpEd. The item asks, “While in school, were you ever classified as a special education student?” This item was coded positive if the participant was enrolled in special education prior to injury because of learning and/or behavior problems in school. This a priori control variable also was ultimately used in the regression analyses.

Pre-injury Working Problems. These data were collected from the pre-injury interview under the variable PrelimWork. The item asks, “At the time of injury were you having difficulty (working) due to a physical, mental, or emotional condition that had been present for at least 6 months?” This item was coded positive if the participant had problems with working due to a physical, mental, or emotional condition that had been present for at least 6 months prior to injury. If the participant was not actively looking for work (e.g., full-time students), it was coded as if they were actively looking for work. For example, although Participant A is a student and not currently looking for work, if they were looking for work, would they have problems with working due to a physical, mental, or emotional condition that has been present for at least 6 months prior to injury? This a priori control variable was not used in the regression analyses because of missingness.

Pre-injury Learning Problems. These data were collected from the pre-injury interview under the variable PrelimLearn. The item asks, “At the time of injury were you having difficulty (learning, remembering, or concentration) due to a physical, mental, or emotional condition that had been present for at least 6 months?” This item was coded positive if the participant had problems with learning due to a physical, mental, or emotional condition that was present for at least 6 months prior to the injury. This a priori control variable was not used in the regression analyses because of missingness.

Urbanicity. TBIMS paid a secondary service provider (GreatData.com) for a zip code-based algorithm to classify its patients based on geographics both at admission and discharge. This algorithm classified patients as living in either rural, suburban, or urban setting. This urbanicity classification was based on three factors: population density, distance from the nearest city, and size of the nearest city. A more detailed description of this process can be found at this website <http://greatdata.com/rural-urban-data>.

For this study, urbanicity prior to admission (where they lived before injured) was utilized. The zip code being classified was derived from the pre-injury history interview by asking the participants, “What was the zip code at the place where you were living before the injury?” The TBIMS zip code at injury variable was called ZipInj and was part of the medical abstraction form. This variable was not used as an additional covariate control in the regression analyses as attrition analyses found that those lost to follow-up and those who attended follow-up did not differ on this variable.

Insurance Type. This variable was a proxy for socioeconomic status and was derived from payor type (primary or secondary) upon acute or rehabilitation admission under the TBIMS variable names of AcutePay1, AcutePay2, RehabPay1, and RehabPay2 that were part of the medical abstraction form. If the payor was listed in any of the four payor sources as Medicaid, it was coded as Medicaid. If it was coded as anything else, it was coded as nonMedicaid. Ultimately, this variable was not used as an additional covariate control in regression analyses as attrition analyses found that those lost to follow-up and those who attended follow-up did not differ on this variable.

Injury Severity. Days in post-traumatic amnesia (PTA) was used to measure injury severity. This calculated TBIMS variable was named PTADays and was computed by

subtracting the date emerged from amnesia from the day of injury. If the participant was in post-traumatic amnesia at rehabilitation discharge the total days of inpatient medical care (acute and rehabilitation) plus one day was utilized (Nakase-Richardson, Sepehri, Sherer, Yablon, Evans, & Mani 2009; Nakase-Richardson et al., 2011). The dates of injury, emergence from PTA, and length of inpatient stay, were part of the medical abstraction form. This a priori control variable was ultimately used in the regression analyses.

Functioning at Neurorehabilitation Discharge. Total FIM score was used to measure the level of independent functioning at discharge. The computed total FIM score was derived from the medical record abstraction form and the name for this TBIMS variable name was FIMTOTD. The subscales of cognitive functioning at discharge (FIMCOGD) and motor functioning at discharge (FIMMOTD) were used for descriptive purposes. The FIM was previously described in Chapter 2 of this document. This a priori control variable was used in the regression analyses.

Mechanism of Injury. Mechanism of injury describes how the injury occurred and is sometimes used as an indicator of injury severity. This TBIMS variable was called Cause and was collected through medical record abstraction. This TBIMS variable has 19 potential responses; similar causes were grouped. Responses in parenthesis are original responses with the categories used in this study as follows: Motor Vehicle (motor vehicle, motorcycle, all-terrain vehicle, other vehicle), Sports (bicycle, water sports, field and track sports, gymnastic activities, winter sports, air sports, other sports), Gunshot Wound (gunshot wound), Violence (assault with blunt instrument, other violence), Fall (fall, hit by falling object), Pedestrian (pedestrian), and Other (other unclassified, unknown). These categories were used to describe this sample. Ultimately, this variable was used as an additional covariate control in regression analyses.

Acute Length of Stay. Acute length of stay was a calculated variable within the TBIMS database and measures total days in acute inpatient medical care by subtracting date of discharge from date of admission. These data were collected through medical record abstraction. The number of days spent in acute inpatient care was used to describe this sample. Ultimately, this variable was not used as an additional covariate control in regression analyses as attrition analyses found that those lost to follow-up and those who attended follow-up did not differ on this variable.

Rehabilitation Length of Stay. Rehabilitation length of stay was a computed variable within the TBIMS database and measures total days in care by subtracting date of discharge from date of admission. These data were collected through medical record abstraction. The number of days spent in inpatient rehabilitation care was used to describe this sample. Ultimately, this variable was not used as an additional covariate control in regression analyses as attrition analyses found that those lost to follow-up and those who attended follow-up did not differ on this variable.

Sample Descriptives. Table 3 included all categorical variables including demographics (sex, race, urbanicity, insurance type), pre-injury characteristics (problematic substance use, special education, learning problems, working problems), mechanism of injury, and exiting type (diploma, GED, dropout) by describing the frequency of attributes in the sample and percentage of the sample with the attributes. Using the Mississippi Intervals, injury severity was classified as moderate TBI (0 to 14 days), moderate-severe TBI (15 to 28 days), severe TBI (29 to 70 days), and extremely severe TBI (> 70 days; Nakase-Richardson et al., 2011). Research question one was answered through the rates of exiting included in this table. It is important to note that some

variables had high levels of missingness. For these variables, the percentage was calculated from the number of participants where this variable was reported.

Table 3

Sample Descriptives: Categorical

Variable	n	%
Male	126	62.4
Age		
16	72	35.6
17	95	47.0
18	35	17.3
Race		
White	152	75.2
Black	25	12.4
Hispanic	20	9.9
Other Race	5	2.5
Payor Source		
nonMedicaid	147	72.8
Medicaid	55	27.2
Urbanicity		
Rural	86	42.6
Suburban	70	34.7
Urban	45	22.3
Pre-injury Substance Use	55	27.2
Pre-injury Special Education	22	10.9
Pre-injury Learning Problems	14	10.4
Pre-injury Working Problems	2	1.5
High School Exiting Types		
Dropout	24	11.9
GED	10	5.0
Diploma	168	83.2
Moderate TBI	64	32.2
Moderate-Severe TBI	56	28.1
Severe TBI	57	28.6
Extremely Severe TBI	22	11.1
Mechanism of TBI		
Motor Vehicle	151	74.8
Sports	12	5.9
Gunshot Wound	8	4.0
Violence	19	9.4
Fall	15	7.4
Pedestrian	10	5.0
Other	1	0.5

Note: Sample ($n = 202$)

Table 4 presents all noncategorical variables and includes injury severity (PTA, length of stay acute, length of stay rehabilitation), level of functioning at inpatient neurorehabilitation discharge (total score, cognitive subscale, motor subscale), and hours of productivity (total, employment, post-secondary education). Table 4 presents variables in terms of quartiles, mean, range, standard deviation, skewness, and kurtosis. When examining the three five-year productivity outcomes, 37% of participants had zero hours of total productivity per week, 57% of participants had zero hours of employment productivity per week, and 67% of participants had zero hours of educational productivity per week. Additionally, 35.6% of the sample reported total weekly productivity (education and employment) to be 35 hours per week or more on average.

Table 4

Sample Descriptives: Noncategorical

Variable	Quartiles	Mean	SD	Range	Skewness	Kurtosis
PTA (days)	12-22-43	33.31	34.05	0 - 226	2.28	6.91
FIM						
Total	81-98-108.5	92.42	23.53	18-126	-1.42	2.06
Cognitive	21-25-29	24.19	7.15	5-35	-0.86	0.58
Motor	60-72-82	68.22	18.46	13-91	-1.32	1.65
Hours Productive						
Total	0-15.5-35	19.10	17.75	0-62.5	0.27	-1.16
Employment	0-0-35	12.70	15.74	0-35	0.53	-1.63
Education	0-0-15.5	6.40	10.80	0-35	1.48	0.79
Acute LOS	10-17-24	19.65	14.13	3-91	2.07	6.05
Rehabilitation LOS	11-20.5-35.25	29.17	28.39	4-193	2.73	10.00

Note: Sample ($n=202$), post-traumatic amnesia (PTA), Functional Independence Measure (FIM), length of stay (LOS).

Procedures

A formal external request of data was submitted to and approved by the Traumatic Brain Injury Model Systems Program. This process took approximately one month. The external request for data document included the title of the project, background/introduction, study aims,

proposed methods, variables requested, and proposed analyses. Once the de-identified data were received via SPSS data file, the sample was restricted using the study-specific inclusion criteria.

Institutional Review Board. This study has been approved by the University of South Florida's Institutional Review Board. There are no known risks to participants in this study and data are de-identified.

Analysis Plan

The following section presents the overall study design, analyses of missingness, exploration of sampling attrition biases, correlational analyses, final selection of variables, and the analyses for research questions one through five. Research question one was discussed in the section on sample description. The descriptive analyses were conducted using Version 24 of IBM Statistical Package for the Social Sciences (SPSS). Regression analyses utilized Mplus Version 7.3 to take into account the nesting of participants within medical centers as the assumption of independence was violated. Standard errors were adjusted for dependence in the responses within centers with the intraclass correlational coefficients calculated to measure the degree of dependence.

Study Design. All data were previously collected as part of the TBIMS program. Therefore, all data analyzed in this study were considered secondary analyses. Description, comparisons (*t*-test, chi-square), and multiple regression analyses were the primary analyses in this study.

Analysis of Sampling Biases. In order to examine if this study's follow-up attrition created a biased sample, those who did not complete five-year follow-up ($n = 42$) were statistically compared to those who attended the five-year follow-up ($n = 202$) at the .05 significance level across all variables (see Table 5). Because of limited power with statistical

testing, differences also were visually analyzed with clinical judgment utilized to determine if variables were potentially confounding. If variables differed between groups, through statistical testing or subjective analyses, they were considered for inclusion in the regression models in order to control for possible confounding. Ultimately, only mechanism of injury was added to the regression analyses to account for potential sampling attrition bias.

Analysis of Missingness. The amount of missing data for each variable was examined and relationships between missingness and other variables were examined. If variables were found to have a high level of missingness they were considered for removal from regression analyses. Ultimately, pre-injury learning problems and pre-injury working problems were removed from regression analyses because of high levels of missingness.

Analysis of Control Variable Interrelatedness. Correlations between control variables were explored prior to primary proposed analyses to examine the level of interrelatedness between variables. When variables were found to be highly related decisions were made regarding entry into regression analyses. No variables were removed because of high levels of interrelatedness.

Selection of Variables for Regression Modeling. Findings from analyses of sampling bias, missingness, and control variables interrelatedness, informed final variable selection. When variables were different between participants who completed follow-up and those who did not they were considered for inclusion in regressions to account for bias. If variables had a high level of missingness they were considered for exclusion. If control variables had a high level of relatedness they were considered for exclusion.

Analysis of Control Variable and Outcome Variable Interrelatedness. Correlations were conducted to describe bivariate relationships between control variables and outcome variables without controlling for other variables.

Research Question 1 Analysis. Research question one was analyzed by examining rates of exiting for the sample.

Research Question 2 Analysis. To answer research question two, all a priori and descriptive variables (i.e., potential confounds) were compared across exiting types. A series of independent *t*-tests and chi-square analyses were used to examine if differences existed across types.

Research Question 3 Analysis. Multiple regression modeling accounting for nesting was used to explore the unique relationship between high school exiting and total hours of weekly productivity. The dependent variable was total hours of weekly productivity five-years post-injury that included hours engaged weekly in employment and postsecondary education. Control variables included selected a prior variables and potentially confounding variables. Final variables entered in modeling were based on findings from analyses of sampling bias, missingness, and predictor variable interrelatedness. Significance testing was conducted at the .05 significance level.

Research Question 4 Analysis. Multiple regression modeling accounting for nesting was used to explore the unique relationship between high school exiting and hours of weekly employment. The dependent variable was hours of weekly employment five-years post-injury. Control variables included selected a prior variables and potentially confounding variables. Final variables entered in modeling were based on findings from analyses of sampling bias,

missingness, and predictor variable interrelatedness. Significance testing was conducted at the .05 significance level.

Research Question 5 Analysis. Multiple regression modeling accounting for nesting was used to explore the unique relationship between high school exiting and hours of weekly post-secondary education. The dependent variable was hours of weekly post-secondary education five-years post-injury. Control variables included selected a prior variables and potentially confounding variables. Final variables entered in modeling were based on findings from analyses of sampling bias, missingness, and predictor variable interrelatedness. Significance testing was conducted at the .05 significance level.

Chapter 4: Results

The aims of this study were to describe high school exiting for students with a TBI and to examine if exiting type is related to future productivity for this vulnerable population. In this chapter, the five research questions utilized to answer study aims are analyzed.

Missingness

In this sample ($n = 202$), no variables other than pre-injury learning problems and pre-injury working problems had more than 3% of data missing. These two variables had data missing for approximately 36% of cases. The reason for these missing data was that these variables were added to the TBIMS database on 7/1/2005, so any participants who completed their baseline prior to this date were not asked this item. These variables were excluded from regression analyses because of large amounts of missing data.

Sampling Comparisons

In order to examine if this study's follow-up attrition criteria created a biased sample, the characteristics of participants who attended the five-year follow-up ($n = 202$) were compared to those who missed the five-year follow-up ($n = 42$) at the .05 significance level across all variables (see Table 5). Independent *t*-tests and chi-square analyses were utilized for comparisons. Compared to participants who missed the follow-up, the participants who attended follow-up were found to be significantly more White (75.2% vs. 54.8%), less Black (12.4% vs. 31.0%), and had more severe injuries as measured by days in post-traumatic amnesia (33.32 vs. 25.61). These differences in race and injury severity are indicative of attrition bias. Because these variables were a priori control variables they were already included in the regression analyses and did not need to be added to account for sampling bias. Although not statistically

different, visual analysis revealed that mechanism of injury appeared to differ between groups especially in terms of motor vehicle accidents (74.8% vs. 59.5%), gunshot wounds (4.0% vs. 9.5%), violence (9.4% vs. 16.7%) and pedestrian injuries (5.0% vs. 9.5%). Because of these apparent differences, mechanism of injury was included in regression analyses as a covariate with motor vehicle accidents as the referent group to account for potential sampling bias.

Table 5

Sample Attrition Comparisons

Variables	Samples	
	Lost to Follow-up (n = 42)	Sample (n = 202)
Male	69.0%	62.4%
White	54.8%	75.2%*
Black	31.0%	12.4%*
Hispanic	11.9%	9.9%
Other	2.4%	2.5%
Medicaid	33.3%	27.2%
NonMedicaid	66.7%	72.8%
Rural	31.0%	42.8%
Suburban	35.7%	34.8%
Urban	33.3%	22.4%
Pre-Injury Substance Use	29.3%	27.8%
Pre-Injury Special Education Status	16.7%	10.9%
Pre-injury Learning Problems	10.5%	10.4%
Pre-injury Working Problems	0.0%	1.5%
Days of Post-traumatic amnesia	25.61	33.32*
FIM Total score	95.18	92.42
FIM Cognitive	26.15	24.19
FIM Motor	68.98	68.22
Acute Length of Stay	18.02	19.65
Rehab Length of Stay	22.79	29.17
Motor Vehicle	59.5%	74.8%
Sports	4.8%	5.9%
Gunshot Wound	9.5%	4.0%
Violence	16.7%	9.4%
Fall	9.5%	7.4%
Pedestrian	9.5%	5.0%
Other	0.0%	0.5%

Note = Functional Independence Measure (FIM). Bold and asterisk indicates significance at the .05 significance level.

Research Question 1

What are the rates of high school exiting (e.g., diploma, GED, dropout) for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

Data to answer research question one were found when sample descriptives were analyzed (see Table 3). It was found that five years after incurring a moderate or severe TBI, 83% graduated with a diploma, 5% earned a GED, and 12% dropped out.

Research Question 2

Do exiting groups differ across descriptive variables and variables related to productivity (demographics, pre-injury functioning, injury severity, functioning at discharge) for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

Several differences were found between exiting groups across categorical variables (see Table 6). In terms of students who earned a diploma (83% of the sample), differences in proportions were found in terms of race (89.5% identified as White, 64.0% Black, 65.0% Hispanic, 60.0% Other Races), insurance type (87.8% not receiving Medicaid, 70.9% receiving Medicaid), pre-injury problematic substance use (86.0% without substance use, 74.5% with substance use), and pre-injury learning problems (86.0% without learning problems, 42.9% with learning problems). In terms of students who earned a GED (5% of the sample), differences in proportions were found in terms of pre-injury problematic substance use (14.5% with substance use, 1.4% without substance use) and pre-injury learning problems (21.4% with learning problems, 4.1% without learning problems). In terms of students who dropped out of high school (12% of sample), difference were found in terms of race (5.9% identified as White, 30.8% Black,

25.0% Hispanic, 40.0% Other Races) and pre-injury learning problems (35.7% with learning problems, 9.9% without learning problems).

Table 6

Comparison by Exiting Type: Categorical

Variables	Exiting type (n = 202)		
	Dropout (n = 24)	GED (n = 10)	Diploma (n = 168)
Male	11.9%	5.6%	82.5%
Female	11.8%	3.9%	84.2%
White	5.9%	4.6%	89.5%
Black	30.8%	4.0%	64.0%
Hispanic	25.0%	10.0%	65.0%
Other	40.0%	0.0%	60.0%
Medicaid	20.0%	9.1%	70.9%
NonMedicaid	8.8%	3.4%	87.8%
Rural	12.5%	4.9%	81.7%
Suburban	8.6%	4.3%	87.1%
Urban	13.4%	6.3%	81.3%
Pre-Injury Substance Use	12.6%	14.5%	74.5%
No Pre-injury Substance Use	10.9%	1.4%	86.0%
Pre-Injury Special Education Status	13.6%	13.6%	72.7%
No Pre-injury Special Education	11.7%	3.9%	84.4%
Pre-injury Learning Problems	35.7%	21.4%	42.9%
No Pre-injury Learning Problem	9.9%	4.1%	86.0%
Pre-injury Working Problems	50.0%	0.0%	50.0%
No Pre-injury working problems	12.0%	6.0%	82.0%
Motor Vehicle	11.6%	4.6%	84.1%
nonMotor Vehicle	13.7%	5.9%	80.4%

Note: Percentages within same cells were compared. Shading indicates differences between cells at .05 significance level.

Differences were also found when examining a range of noncategorical variables (see Table 7). All data reported below are means. Specifically, differences were found in terms of days of post-traumatic amnesia (PTA; dropout = 49.74, GED = 40.80, diploma = 30.59) and across all three Functional Independence Measure (FIM) at discharge indices, including total score (dropout = 73.96, GED = 88.90, diploma = 95.29), cognitive score (dropout = 18.08, GED = 25.60, diploma = 24.98), and motor score (dropout = 55.88, GED = 63.30, diploma = 70.29).

Additionally, groups differed on days of acute stay (dropout = 26.08, GED = 24.50, diploma = 18.44) and across all three productivity outcomes: hours of employment per week (dropout = 3.56, GED = 12.50, diploma = 14.02), hours of education per week (dropout = 1.46, GED = 0.00, diploma = 7.48), and total productivity per week (dropout = 5.02, GED = 12.50, diploma = 21.50).

Table 7

Comparison by Exiting Type: Noncategorical

Variables	Dropout (n =24)	GED (n =10)	Diploma (n =168)
Post-traumatic amnesia (days)	49.74 (42.16)	40.80 (31.45)	30.59 (32.43)
FIM Total score	73.96 (31.44)	88.90 (21.49)	95.29 (21.14)
FIM Cognitive score	18.08 (8.81)	25.60 (4.95)	24.98 (6.59)
FIM Motor score	55.88 (23.91)	63.30 (20.82)	70.29 (16.74)
Acute Length of Stay (days)	26.08 (18.66)	24.50 (14.26)	18.44 (13.14)
Rehab Length of Stay (days)	38.17 (41.57)	32.80 (18.71)	27.67 (26.67)
Employment Productivity (hours/week)	3.56 (10.18)	12.50 (16.33)	14.02 (15.99)
Education Productivity (hours/week)	1.46 (7.14)	0.0 (0.0)	7.48 (11.23)
Total Productivity (hours/week)	5.02 (12.00)	12.50 (16.33)	21.50 (17.56)

Note: Values within same cells were compared. Shading indicates differences between cells at .05 significance level. Values reported are means and values reported in parenthesis indicate standard deviations.

Control Variable Interrelatedness

Pearson product-moment correlations were conducted to examine the relations among the control variable interrelatedness and potential colinearity. Only one combination of control variables had more than a mild correlation. FIM total score and PTA had a moderate relationship (-.631). This relationship was not unexpected as level of injury severity is theoretically inversely related to functioning. Additionally, among outcomes, weekly hours of post-secondary education and weekly hours of employment were found to have a mild inverse relationship (-.145).

Final Control Variable Selection for Regression Analyses

Variables selected for regression analyses included the a priori control variables of sex, race, pre-injury problematic substance use, pre-injury special education, total FIM at rehabilitation discharge, and days of PTA. Pre-injury problems with learning and pre-injury problems with working were omitted because of a high level of missingness. Pre-injury working problems also had a lack of variability (2 yes, 136 no). Although not statistically significant, mechanism of injury was added as an additional covariate as it appears to differ between participants who attended five-year follow-up and those who did not. Motor vehicle accident was used as the referent group for mechanism of injury dummy coding.

Research Question 3, 4, and 5

RQ3. What is the unique relationship between high school exiting type and total weekly hours productive (i.e., hours engaged in post-secondary education and employment) at 5-years post-injury for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

RQ4. What is the unique relationship between high school exiting type and total weekly hours engaged in employment at 5-years post-injury for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

RQ5. What is the unique relationship between high school exiting type and total weekly hours engaged in postsecondary education at 5-years post-injury for adolescents who suffered a moderate or severe traumatic brain injury and attended inpatient neurorehabilitation prior to high school exiting?

The intraclass correlations (ICC) were estimated for all outcomes with minimal nesting observed (total productivity ICC = .001, employment productivity ICC = .001, productivity education ICC = .017). To account for the minimal, but present nesting of the data, robust maximum likelihood estimation was utilized for modeling (Caladiore & Ghaoui, 2001). Regression coefficients (b), standard errors (SE), and bivariate correlations (*r*) were reported for all outcomes. Significance testing was conducted at the .05 significance level (see Table 8). All variables were put in the models simultaneously. Overall, all three models were found to be significant with Total, Employment, and Education models of productivity respectively accounting for 30.2%, 22.7%, and 16.2% of total variance explained (r^2).

Table 8

Models of Productivity

	Total			Employment			Education		
	b	SE	<i>r</i>	b	SE	<i>r</i>	b	SE	<i>r</i>
Female ^a	0.86	2.58	-.03	-0.66	1.81	-.06	1.52	1.47	.04
Black ^b	-11.60*	5.11	-.21	-10.17*	4.00	-.21	-1.43	2.59	-.04
Hispanic ^b	-5.82*	2.36	-.09	-4.21*	1.91	-.04	-1.61	1.51	-.08
Other Race ^b	-3.89	5.97	-.08	-12.15*	4.35	-.13	8.27	5.68	.06
Substance Use	-5.41	3.15	-.07	-1.01	3.28	.05	-4.40*	1.62	.19
Special Education	-7.55*	3.71	-.16	-7.74*	1.90	-.15	0.19	3.34	-.05
PTA	-0.14*	0.03	-.37	-0.10*	0.02	-.32	0.04	0.02	-.14
FIM Total	0.12	0.06	.38	0.10*	0.04	.35	0.01	0.04	.11
Sport Injury ^c	4.44	8.73	.13	-3.76	5.30	.02	8.19*	3.70	.19
Gun Injury ^c	7.08	6.63	-.06	-0.50	5.31	-.08	7.57	5.72	.03
Violence Injury ^c	-2.00	5.16	-.01	-0.80	6.63	.02	-1.19	3.00	.04
Fall Injury ^c	0.06	6.28	.03	-0.84	7.55	.04	0.90	3.75	.00
Pedestrian Injury ^c	-1.57	4.16	-.05	1.09	4.47	.01	-2.65	1.96	-.10
Other Injury ^c	-5.82*	2.43	-.05	-8.26*	1.65	-.06	2.45	1.44	.01
GED ^d	6.23	4.02	-.09	4.63	3.94	.00	1.60	1.81	-.14
Diploma ^d	7.77*	3.72	.32	2.03	3.45	.19	5.74*	1.49	.22

Note: Bold and asterisk indicates significance at the .05 significance level. Male is the referent for Sex as indicated by ^a, White is the referent for Race as indicated by ^b, Motor Vehicle Accident is the referent for Mechanism of Injury as indicated by ^c, and Dropout is the referent for Exiting Type as indicated by ^d.

After controlling for known predictors of productivity after TBI (sex, race, pre-injury functioning, PTA, functioning at discharge) and additional control (i.e., mechanism of injury), it

was found that exiting with a diploma accounted for a statistically significant estimated increase of 7.77 hours per week of total productivity (education, employment) above the referent group of dropout. In addition to exiting with a diploma, five control variables were found statistically significant in the modeling of total productivity. Identifying as Black accounted for an estimated loss of 11.60 hours of total productivity per week compared to the referent group of White. Similarly, identifying as Hispanic accounted for an estimated loss of 5.82 hours of total productivity per week compared to the referent group of White. Being classified as a special education student prior to injury accounted for an estimated loss of 7.55 hours of total productivity compared to not being classified as a special education student. Suffering an injury from the mechanism of “Other injury” accounted for a loss of 5.82 hours of total productivity per week compared to the referent group of motor vehicle accident. Finally, each day of PTA accounted for an estimated loss of 0.14 hours of total weekly productivity.

The same analyses were then conducted with total productivity divided into post-secondary productivity and employment productivity. In terms of post-secondary productivity, exiting with a diploma was found to account for an estimated 5.74 hours of post-secondary education per week above dropping out. Additionally, two control variables were found significant for this outcome (e.g., substance abuse, sports injury). Pre-injury problematic substance use accounted for an estimated loss of 4.40 hours of educational productivity per week compared to those without pre-injury substance problems and participants who incurred their injury through sports had an increase of 8.19 hours of post-secondary weekly productivity compare to those who were injured from motor vehicle accidents.

In terms of average weekly hours of employment productivity, neither form of exiting (e.g., diploma, GED) was found uniquely associated with outcome above dropout, but several

control variables were found significant. Compared to the referent race (i.e., White), identifying as Black, Hispanic, or Other Race, were associated with r estimated losses of 10.17, 4.21 and 12.15 hours of weekly employment, respectively. Being classified as a special education student pre-injury was associated with an estimated loss 7.74 hours of weekly employment compared to not being a student in special education. Each day of PTA was associated with loss of 0.10 hours of weekly vocational productivity while each point of on the total FIM score was associated with an increase in 0.10 hours of productivity. Finally, the covariate of Other Cause of Injury was associated with a decrease of 8.26 hours of weekly vocational productivity compared to the referent of motor vehicle accident.

In addition to research questions three, four, and five, the interactions between race and exiting were explored as the literature indicates both race and exiting type influence productivity. The same predictors and outcomes used in research questions three, four, and five were used for these analyses. In the first exploratory analysis, an interaction between Black and exiting type was explored across all three productivity outcomes. No significant interactions were found. Because cell counts were low and in turn inflated the standard errors, the model was adjusted with the variable of race collapsed into Majority (White) vs. Minority (Black, Hispanic, Other Race) and exiting type collapsed to diploma vs. nondiploma (dropout, GED). However, even with this adjusted variable, no significant interactions were found across the three outcomes explored.

Chapter 5: Discussion

This study explored the intersection of TBI and high school exiting for adolescents who attended inpatient neurorehabilitation. The first aim of this study was to describe the rate of high school exiting and the differences between exiting groups across a range of variables. The second aim of this study was to explore if high school exiting is uniquely related to future productivity. Findings have the potential to influence clinical practice, future research, and policy.

Aim 1- Findings and Implications

For adolescents with a moderate or severe TBI who attended inpatient rehabilitation prior to high school exiting, results indicated that 82% earned a diploma, 5% earned a GED, and 13% dropped out by five years after injury. These are the first known exiting data from a strictly adolescent TBI inpatient neurorehabilitation sample. Comparing findings on high school exiting rates between any two studies is difficult as differences exist between exiting metrics, populations, and years examined. This is especially true with this study that featured a population different from populations that have been explored in the existing literature. With these limitations considered, placing these findings within the context of the current exiting literature provides the foundation for future research, clinical practice, and policy.

High school exiting rates for this sample (adolescents with a TBI who went to inpatient rehabilitation) were compared to the literature on exiting rates for the general student population, students in special education, and students in special education qualified under TBI. Generally speaking, the high school exiting rates found in this study appear to be similar to exiting rates in

the general student population and similar to exiting rates for students in special education classified under TBI. However, there appear to be differences when comparing this sample to students in special education (across categories).

Hull (2009) used U.S. Census data to estimate the high school exiting rates by eight years after anticipated graduation for all U.S. high school students (2.9 million) who were high school freshman in 1988. Eight years after anticipated four-year graduation, 83.5% earned a diploma, 7.7% GED, and 9.4% dropped out. In Hull's study, the rates of exiting were similar to this study's sample of adolescents with a TBI (diploma 83.5% vs. 83.2%, GED 7.7% vs. 5.0%, dropout 9.4% vs 11.9%). Although Hull's study had a much longer follow-up timeline, the percentage of students earning a diploma likely were not significantly influenced by this timeline as students are allowed to stay in public education up until age 21. However, the 2.7% difference in GED attainment and 2.5% difference in dropouts could have been influenced by the longer follow-up timeline as students may earn a GED at any point after leaving high school. This would increase the percentage of those earning a GED and lower the dropout percentage. In a similar study, the U.S. Department of Education (Chapman, Laird, & KewalRamai, 2011) looked at exiting rates between 1972 and 2009 of all high school students. They found that high school completion (including both diploma and GED) increased from 82% to 90% over time. When examining just 2009, they found 85% of students exited with a diploma, 5% with a GED, and 10% of students dropped out. These are again similar to the rates found in this current study (diploma 85% vs. 83.2%, GED 5% vs. 5%, dropout 10% vs. 11.9%). Murnane (2013) reported similar findings when looking at all students in the U.S. between 1970 and 2010 and found that diploma rates ranged from 77.6% to 83.7% for young adults between the ages of 20 to 24. Overall, rates of exiting for the general student population appear to be similar to the rates found

in this current study (TBI with inpatient neurorehabilitation). This is a striking finding as students with a serious TBI experience a significant disruption to their educational progression and severe insult to their central nervous system, yet they are exiting with similar rates to their peers.

One possible explanation for these similar rates is that because all students in the current study were between the ages of 16 and 18 at injury, that many could have been injured very close to their anticipated graduation date. In these instances school staff may have made the decision to let these students graduate with their peers for social reasons (Todis & Glang, 2008) regardless of their functioning or remaining high school requirements. Another possible explanation for these similar rates is that timing of graduation (on-time vs. delayed) was not examined in this current study. It is possible that differences in rates would be found if four year exiting rates were compared. This is plausible as many student with a serious TBI are advised to stay in school longer than four year, often until the age of 21, in order to receive additional services that they would not receive if they exited high school (Brain Injury Network, 2008; Semrud-Clikeman, 2010). Differences based on exiting timing would have been undetected in this current study as it was not possible to determine the exact date of exiting. Finally, specialized TBI inpatient rehabilitation is often unavailable for children and adolescents with TBI. It is possible that unknown contributing factors (e.g., high parental support and advocacy, other access to care) may have led this sample to both receive uncommon care and to have better than normal rates of high school exiting.

The exiting data from this study also can be compared to data on exiting rates for students receiving special education services, both for students qualified under TBI and other categories. Wagner and colleagues (2005) described exiting rates for 11,000 cross categorical special

education students two years after high school exiting. They found that across categories, 68% of these students earned a diploma, 4% earned a GED, and 28% dropped out. These data appear different than the findings from this current study in terms of diploma (68% vs. 83%) and dropout (28% vs. 11.9%). When Wagner and colleague looked at exiting rates specifically for students qualified for special education under the classification of TBI, they found that students with a TBI completed high school (including diploma or GED) more often (79% vs. 72%) and dropped out less (21% vs. 28%) than students receiving special education services across categories. Compared to Wagner's findings, rates from this current study more closely resemble the TBI group (completed high school 88% vs. 79%; dropped out 12% vs. 21%) than they do the general special education group (completed high school 88% vs. 72%, dropped out 12% vs. 28%). A similar pattern is found when examining the publically available NCES (2014) data on all students exiting special education (diploma 66%, GED 14%, dropout 20%) and those qualified under TBI. When compared to the NCES data from 2014, rates from this current study more closely resemble the TBI group (diploma 83% vs. 69%; GED 5% vs. 15%; dropout 12% vs. 12%) than the overall exiting rates for students in special education (diploma 83% vs. 66%; GED 5% vs. 14%; dropout 12% vs. 20%). This is especially true when high school completion (diploma or GED) vs noncompletion (dropout) is examined. When taken as a whole, adolescents in the study appear to exit at rates more similar to students with a TBI qualified for special education than the overall special education population. In addition, all three data sources support that students with a TBI generally complete high school at higher rates than other students participating in special education.

Reasons for these consistent findings are not clear and should be examined in future studies. When considering the Wagner study and the NCES data, it is possible that many of the

students qualified under TBI had relatively mild or isolated impairments and are more easily managed in the educational setting when compared to students with more global disabilities. This is plausible as approximately 80-90% of TBIs are of the mild variety. This however would not explain relatively better rates in this study's sample, of severely injured youth, when compared to overall special education. Another possible explanation stems from a TBI being caused by an event that can occur at any time in development vs. other disabilities that have an early onset (e.g., intellectual disability, autism, emotional disturbance, learning disability). Because learning is a cumulative process, an event based disability (TBI) later in education may not affect a student's education and in turn their exiting as much as earlier onset disabilities and their cumulative effects. For example, a student who suffers a TBI when they are 15 years old has two years of pre-exiting hardship after years of typical progression, while a student with autism may have struggled for years and fallen farther and farther behind. These are possible explanations, but further inquiry is needed to understand why students with a serious TBI appear to exit better than other students in special education.

There are only two known studies that focused on youth with a TBI and reported data on high school exiting rates (Kriel et al., 1988; Todis et al., 2011). Unfortunately, both of these studies had methodological limitations or differences that make it difficult to compare their findings to the findings from the current study. Kriel and colleagues found that 64% of students graduated with a diploma or special education certificate while 29% dropped out (7% still in school at follow-up). This study had a number of methodological limitations (large attrition rate, small sample), but was the first known study to document exiting rates for students with a TBI. Todis and colleagues found that 94% of participants had completed high school with only 6% dropping out. Although this study was methodically sound, the data on high school exiting were

not the primary focus and included participants who had their injuries both prior to and after high school exiting.

Although data exist on rates of high school exiting for a variety of populations, including the general student population, students in special education, students in special education qualified under TBI, and very limited data for youth with a TBI, this is the first study to explicitly examine rates of exiting for students with moderate or severe TBI who attended inpatient neurorehabilitation. When placed in the context of existing literature on high school exiting, students in this study appeared to exit at rates similar to the general population. This is a remarkable finding considering the consequences of a significant brain injury. This finding has the potential to be informative for both medical and educational professionals for educational planning and related communication.

Prior to discussing the potential clinical implications of these findings it is important to stress cautious in their analysis and application. Caution should be taken in clinical application as these are the first reported data on exiting rates for students who attended inpatient neurorehabilitation after a serious TBI. Strong clinical utility will only be appropriate if these findings are replicated using different methods and samples. With those considerations being stated, these data have the potential (i.e., with replication) to assist professionals in communicating expectations to injured students and their families by saying things like, “Although there are a lot of factors that go into transitioning back to school, many students with a serious TBI go on to graduate high school with a diploma, and in fact, the rates of graduating with a diploma are very similar to students without a brain injury.” These types of statements are important because injured individuals often are unsure and worried about how their life will be changed because of their injury and how it will affect the attainment of meaningful

developmental milestones. Additionally, knowing that over 80% of adolescent students with a TBI who attend inpatient neurorehabilitation graduate high school can make the goal of graduating with a diploma the norm rather than the exception. If graduation is viewed as the norm it may help facilitate the medical to school connection and start the educational planning process earlier than if the rate isn't known and professionals take more of a wait and see approach that in turn may delay service. Although the same caution must be taken regarding clinical utility, the findings from exiting group comparisons (research question two) may build upon the above mentioned foundational data on high school exiting rates after TBI inpatient rehabilitation by adding information that can aid in the formulation of more nuanced statements regarding factors related to graduating with a diploma, earning a GED, and dropout.

Differences in exiting groups were found when examining race, insurance type (proxy for socioeconomic status), pre-injury substance use, pre-injury learning problems, injury severity (PTA), functioning at discharge (total, motor, cognitive), and acute length of stay. Professionals may make better predictions regarding high school exiting outcomes by considering these differences. In this section, protective factors will be defined as differences associated with diploma and risk factors will be defined as differences associated with dropping out of high school. This is appropriate as much of the broad literature on high school exiting supports that earning a diploma is related to a range of perceived positive outcomes while dropping out is related to a range of perceived negative outcomes.

Based on the results of this current study, professionals may be able to make more precise predictions by considering protective factors for exiting with a diploma including identifying as White, not receiving Medicaid, no pre-injury problematic substance use, no pre-injury learning problems, lesser injury severity (days of PTA), higher functioning at discharge as measured by

the FIM (total score, motor, cognitive), and a shorter stay in acute medical care. Risk factors for dropout include identifying as a minority (Black, Hispanic, Other Race), receiving Medicaid, having a pre-injury learning problem, more severe injury (days in PTA), lower functioning at discharge as measured by the FIM (total score, motor, cognitive), and a longer stay in acute medical care.

To highlight how these protective factors and risk factors would be used in practice two cases are described. Student A has no pre-injury substance use or learning problem, experienced a relatively brief duration of PTA, and had minimal acute medical complications so his acute medical stay was brief. His medical team may take these variables into consideration and be able to make more confident predictions regarding high school exiting. This more confident prediction has the potential to influence rehabilitation goals, transition planning, and when communicating with the adolescent, their family, and the school. Statements like this could be made, “We know that you are concerned about transitioning Student A back to school. Based on the research we know that generally 80% of adolescents with serious TBI graduate with a diploma which is similar to students without a TBI. We feel extra confident that we should be preparing Student A for an educational plan with the goal of graduating because of this and also because he has several protective factors associated with graduating high school.” Conversely, Student B had pre-injury learning problems, spent over 30 days in acute medical care, and has low functional motor and cognitive scores at inpatient rehabilitation discharge. In a case presentation like this the medical team could make a statement like this, “We know that you are concerned about transitioning Student B back to school. Based on the research we know that generally 80% of adolescents with serious TBI graduate with a diploma which is similar to students without a TBI. However, Student B has a couple risk factors that lead us to believe he

may have a more difficult time graduating with a diploma. If graduating is important, we would recommend additional services to increase his functioning (cognitive, motor) and extra supports to help his learning.” Some risk factors have the potential to be changed through individual intervention (substance use, learning problems, functioning) while others do not (race, insurance type). Factors such as race and SES (insurance type) are likely best addressed through policy change similar to what has occurred and is still occurring with the general U.S. student population (Murnane, 2013). It is beyond the realm of this current study to differentiate if the differences found are a product of disproportionality at large or if there is a unique effect for students with a TBI. This is a potential target for future research and policy.

It is important to state that these current findings on exiting rates and exiting group difference for adolescents who attended inpatient neurorehabilitation after a serious TBI are the first data observed for this unique population. These rates and differences should be observed with different samples and methodologies before strong statements can be made regarding their validity and clinical significance. Additionally, although high school exiting matters for the general population (Berkthold, Geis, & Kaufman, 1998; Cameron & Heckman, 1991; Hull, 2009; Kienzel & Kena, 2006; Julian & Kominski, 2011; Wagner et al., 2005), it may not necessarily matter for students with a serious TBI. It is possible that exiting type is not associated with meaningful outcomes for this population as other factors (demographics, pre-injury functioning, injury severity, functioning at discharge) account for the majority of variance in outcome. The next section will discuss findings from this study regarding exiting and its relationship with future productivity. While this first section described rates of exiting and what variables are related to exiting, this next section will be the first attempt at understanding if exiting matters for students with a TBI who attend inpatient neurorehabilitation.

Aim 2- Findings and Implications

The second aim of this study was to explore if high school exiting was uniquely related to five-year productivity. Productivity was defined as weekly hours engaged in education, weekly hours engaged in employment, and their summation (total productivity). In this section, findings from this study related to total productivity, educational productivity, and vocational productivity will be discussed in that order. They will then be put into the context of the current literature and implications discussed.

In this current study a unique relationship was found between exiting with a diploma and productivity when examining the outcomes of total hours of productivity per week and total hours of education per week. Total hours of employment per week was better explained by several established predictors of productivity (race, special education, PTA, FIM). Based upon the findings from this study, exiting high school with a diploma is related to overall future productivity and future educational productivity for students with a serious TBI who attend inpatient neurorehabilitation. It also is noteworthy that this relationship doesn't appear to exist when examining only employment productivity. These mixed findings regarding the unique relationship of exiting with a diploma to outcome (total productivity, educational productivity, employment productivity) for students with a TBI has the potential to contribute to the literature and has implications for future research, policy, and clinical practice. It is important to note that GED was not found significant in any of the productivity models explored. It is likely that the relatively small number ($n = 10$) of students exiting with a GED in this sample contributed to a lack of statistical power. Accordingly, the association of GED and future productivity should be examined further in future studies with larger samples.

The findings from this study support the assumption that high school exiting matters for students with a TBI (Brain Injury Network, 2008; Semrud-Clikeman, 2010; Todis & Gland, 2008). Previously, this assumption had been based on the overall high school exiting literature (Chapman, Laird, & KawalRamani, 2011; Ou, 2008; Wagner et al., 2005) and did not take into account the possibility that this assumption does not hold for this unique population as other factors specific to TBI (e.g., injury severity, pre-injury functioning, functioning at discharge) may play a more prominent relationship to outcome than exiting. The finding that exiting is uniquely related to productivity (total, educational) for student with a TBI is particularly aligned with similar findings using other populations showing a relationship between exiting and productivity (Berkthold, Geis, & Kaufman, 1998; Cameron & Heckman, 1991; Hull, 2009; Kienzel & Kena, 2006; Julian & Kominski, 2011; Wagner et al., 2005). Real world implications of this finding are that exiting high school with a diploma does appear to have a relationship with overall productivity after TBI and therefore graduating with a diploma should be encouraged. While findings for aim one of this study provided evidence for rates of exiting as well as protective and risk factors, these findings regarding the relationship between exiting and productivity support why those predictions matter and why it is important to support students in attaining a diploma after a serious TBI. To take a more nuanced view of the relationship between exiting and future productivity, total productivity was divided into hours of employment and hours of education.

Earning a high school diploma appears to open the door for post-secondary educational opportunities that the GED and dropping out do not. This is congruent with the literature on high school exiting and the requirements needed to attend post-secondary education (Berkthold, Geis, and Kaufman, 1998) although there is some literature reporting that earning a GED also allows

for post-secondary education opportunities (Cameron & Heckman, 1991; U.S. Census Bureau, 2008). Pre-injury problematic substance use also appears to be linked to limit post-secondary opportunities after brain injury. These findings regarding the relationship between post-secondary productivity and exiting have two major implications for student seeking post-secondary education after TBI. First, earning a high school diploma will better the chances of post-secondary engagement and therefore efforts to earn a diploma should be supported to reach this goal. Secondly, if the student has a pre-injury substance abuse concern, it may be beneficial to intervene upon this issue as it is negatively related to post-secondary productivity.

Unlike educational productivity, vocational productivity was not related to high school exiting and was instead related to other variables that were used as control variables in this study. These control variables (race, special education, PTA, functioning) were chosen as their links to productivity after TBI are well documented so their significance was not a surprise. What was unexpected was that earning a diploma or GED did not significantly increase the hours spent on productive employment as it did when examining both total productivity and educational productivity. It is important to note that GED was associated with 4.63 more hours of employment per week than dropout, but that the standard errors were too large to detect significance ($SE = 3.94$ hours). There is no obvious reason why diploma was not uniquely related to hours of employment per week. The most plausible explanation is that earning a diploma simply did not have as big of an influence on working a job as other variables and therefore was not statistically unique. This appears more plausible when univariate correlations between predictors and hours employment are observed and compared to the correlations between predictors and education. For hours of employment other factors simply may mean

more (race, special education, PTA, FIM) than earning a diploma. This is worth exploring in future studies.

Perhaps the most powerful implications from this study are evidenced when the findings from aim one and aim two are combined. Aim one tells us that high school exiting is the norm, rather the exception, for students in this study with a serious TBI who attend inpatient neurorehabilitation. This is an unanticipated finding and may offer hope to injured students, their families, and professionals. These foundational data may also spur future research into studying how to best promote educational progression after TBI. The data from aim one also tell us what factors relate to earning a diploma. These data can aid in prognostication, serve as targets for intervention, and deserve further scientific inquiry. While aim one tells us how students exit and what traits are related, aim two provides evidence that exiting matters. This is an important chain of knowledge, but it is just the start. Future studies would benefit from examining timing of diploma, different outcomes (e.g., mental health, subject well-being, independence), and outcomes at different time points.

Limitations

There are a number of limitations to this study. First, the sample utilized had a truncated age range of 16-18 years old. Younger teens and children who experience a TBI may have different experiences than injured adolescents who are a year or two away from graduation. Secondly, the sample in this study included only individuals who attended inpatient neurorehabilitation after a moderate or severe TBI in accordance with the TBIMS inclusion/exclusion criteria. Individuals with less severe injuries, or those who do not go to inpatient neurorehabilitation, may have different experiences than the sample in this study. Thirdly, the design was correlational, and thus causal inferences are not warranted. An argument

also could be made for alternate control predictors to have been used in this study. The predictors in this study were chosen as they appear to have substantial evidence in the TBI and educational literature in terms of being related to future productivity. Fourthly, the outcome of hours of productive activity has its limitations. It could be argued that more time spent in education is not always the best and that level of achievement would be a better metric. This is a valid argument and hours of productivity (employment, education, total) is simply one way to quantify outcome. Other outcomes need to be explored before it can be definitively stated that high school exiting matters for students with a TBI. Finally, because inpatient neurorehabilitation is generally uncommon for children and adolescents, it is possible that unaccounted potential confounds existed (e.g., high parental support and advocacy, other beneficial care) that made this sample different from the general population and influenced the findings on rates of high school exiting and future productivity.

Conclusion

There is substantial evidence that suffering a TBI has the potential to decrease future productivity. This study provides two major contributions to the literature. First it provides preliminary evidence that students with a moderate to severe TBI who attend inpatient neurorehabilitation exit high school at rates similar to the general student population. This is noteworthy as students with a TBI often face significant impairment and educational disruption. To further this finding, potential protective factors and risk factors related to exiting were identified. If replicated in future studies, the knowledge gained about rates, protective factors, and risk factor, can be utilized to provide a normative reference, instill hope, spur medical to educational collaboration, provide target points for intervention and policy, and serve as the foundation for future research. The second contribution to the literature is evidence that high

school exiting (i.e., diploma) is related to total productivity and educational productivity but not vocational productivity after TBI. This study provides preliminary evidence that for adolescents with a serious TBI who attend inpatient neurorehabilitation, earning a diploma is attainable, there are things that can be done to promote it, and that it matters. Finally, this was the first study utilizing the TBIMS database specifically isolating an adolescent subsample. Future studies may replicate this sampling methodology to further explore ways to enhance the lives of adolescent recovering from a serious TBI.

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