2022

Sociodemographic and Injury Severity Characteristics as Predictors of Functional Independence in Older Adults with TBI up to 10 Years Post Injury

Carmen M. Tyler
Virginia Commonwealth University

SOCIODEMOGRAPHIC AND INJURY SEVERITY CHARACTERISTICS AS PREDICTORS OF FUNCTIONAL INDEPENDENCE IN OLDER ADULTS WITH TBI UP TO 10 YEARS POST INJURY

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

by

Carmen M. Tyler
Master of Arts in Psychology, Cleveland State University, May 2017
Master of Education in Clinical Mental Health Counseling, Cleveland State University, May 2018

Director: Paul B. Perrin, PhD
Professor of Psychology
Department of Psychology

Virginia Commonwealth University
Richmond, Virginia
April, 2022

Acknowledgments

I would like to express my gratitude to those who have been instrumental in supporting me throughout this educational adventure, especially my husband Tim, who has always believed in me and encouraged me to keep working toward my goals. I am extremely grateful for my advisor, Dr. Paul Perrin, who has provided invaluable support and counsel during my tenure at VCU and is truly the epitome of what a mentor should be. My dissertation committee, Dr. Paul Perrin, Dr. Juan Carlos Arango-Lasprilla, Dr. Daniel Klyce, Dr. Natalie Dautovich, and Dr. Bruce Rybarczyk, has my deep appreciation for their invaluable suggestions for refining this study. Last in order but not in importance, I would like to thank my dear cohort-mates, future PhDs Lisa Fuentes, Sarah Ghose, and Sahar Sabet, for constantly rooting for me, providing listening ears and sound advice, and reminding me to celebrate my achievements—you are the unexpected treasures I gained in this journey!

The Traumatic Brain Injury (TBI) Model Systems National Database is a multicenter study of the TBI Model Systems Centers Program, and is supported by the National Institute on Disability, Independent Living and Rehabilitation Research (NIDILRR) a center within the Administration for Community Living (ACL), Department of Health and Human Services (HHS). However, these contents do not necessarily reflect the opinions or views of the TBI Model Systems Centers, NIDILRR, ACL or HHS.

Table of Contents

List of Tables

List of Figures

Abstract

SOCIODEMOGRAPHIC AND INJURY SEVERITY CHARACTERISTICS AS PREDICTORS OF FUNCTIONAL INDEPENDENCE IN OLDER ADULTS WITH TBI UP TO 10 YEARS POST INJURY

By Carmen M. Tyler, MA, MEd

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

Virginia Commonwealth University, 2022

Major Director: Paul B. Perrin, PhD, Professor, Department of Psychology

Traumatic brain injury (TBI), a wound to the brain caused by an external force and resulting in changes in consciousness, memory, or function, may be experienced along a wide range of severity and duration. It can cause momentary confusion or disorientation to lifelong physical and cognitive impairments. There are over 150 TBI-related deaths occurring each day in the U.S., and mortality rates are higher for those who are older, male, single, and unemployed. TBI incidence rates have been increasing in recent years, with the greatest number of TBIs and the highest morbidity and mortality rates in individuals aged 80 and over. As average life expectancy continues to increase, the older adult population is expected to comprise nearly one-quarter of the U.S. populace by 2060, with approximately 19 million individuals aged 85 or older. With the increased risk to a larger proportion of the U.S. population posed by TBI, the aim of the current study was to use hierarchical linear modeling (HLM) to examine the roles of sociodemographic and injury severity characteristics as predictors of functional independence trajectories across 1, 2, 5, and 10 years after TBI in older adults. Participants comprised 2,459 individuals who were aged 60 or older at the time of TBI, enrolled in the national longitudinal TBI Model Systems database, and had Functional Independence Measure Motor and Cognitive subscale scores and Glasgow Outcome Scale-Extended scores on at least 1 time point. The main HLM analyses showed that functional independence trajectories generally decreased over the 10 years after TBI. Individuals who were older, male, underrepresented minorities, had lower education, were unemployed at time of injury, had no history of substance use disorder, or had difficulties with learning, dressing, and going out of the home prior to the TBI, or longer time in posttraumatic amnesia had lower functional independence trajectories across at least one of the functional independence outcomes. Functional independence trajectories were significantly predicted by interactions between time terms and: age, race/ethnicity, employment at baseline, injury severity, and pre-TBI limitations in learning, going out of the home, and working. The sociodemographic and injury severity characteristics identified in this study as predictors of functional independence in older adults with TBI may serve patients and care providers by heightening awareness of the need for attention to these factors in treatment planning and long-term health monitoring and ultimately as a way to decrease morbidity and mortality in this older adult population.

Vita

Carmen M. Tyler was born on August 21, 1959 in Cleveland, Ohio. She worked for Cleveland State University as an interventionist on the ANSWERS-VA study for veterans with brain injury and their caregivers from August 2014 to April 2016. Carmen worked as a research assistant for the Center for Applied Research in Dementia from June 2016 to June 2017. She currently works for Virginia Commonwealth University as an interventionist on the REACH Hope study for caregivers of veterans with dementia and traumatic brain injury. Carmen received her Associate of Arts degree in Psychology from Santa Fe College in 2011, her Bachelor of Science degree in Psychology from Saint Leo University in 2014, her Master of Arts in Psychology from Cleveland State University in 2017, and her Master of Education in Clinical Mental Health Counseling from Cleveland State University in 2018.

Chapter 1: Literature Review

Overview of the Literature Review

This review of the literature begins by defining traumatic brain injury (TBI) and describing severity parameters and the indices commonly used to measure them. Incidence, distribution, sequelae, and determinants of TBI generally are summarized before honing in on these same descriptors as applied to the older adult population. Risk factors preceding and subsequent to TBI in older adults are then briefly examined. The concepts of functional independence and global outcomes after TBI are presented, followed by descriptions of the Functional Independence Measure (FIM) and the Glasgow Outcome Scale-Extended (GOS-E), as well as their reported utility for measuring functional independence after TBI. An overview of demographic factors related to functional outcomes after TBI is provided, including age, insurance status, racial/ethnic minority status, sex and partnered status, employment, and pre-existing health conditions. Finally, this literature is synthesized to describe the purpose of the current study and directional hypotheses based on that literature.

Epidemiology & Pathophysiology of Traumatic Brain Injury (TBI)

TBI may be defined as the damage incurred by the brain from an external force like a fall, a blast, or a blow to the head which results in functional impairment and a change in consciousness (BIA, 2011; NDSC, March, 2017). According to the *Diagnostic and Statistical Manual of Mental Disorders* (5^{th} ed.; *DSM-5*; American Psychiatric Association [APA], 2013), to be considered a TBI it must result in consciousness loss, amnesia, disorientation and confusion, or evidence of neurological deficits. Impairment in function and degree of consciousness change resulting from a TBI will depend on the part of the brain involved and injury severity.

TBI sequelae may range from momentary changes in consciousness (e.g., minutes-long disorientation) to coma and from transient memory difficulties to lifelong deficits in mental status and functioning. TBI may affect a single or multiple domains; for example, a person with TBI may exhibit sensory, movement, memory, cognition, or emotional changes or a combination thereof (CDC, 2015; CDC, 2019; APA, 2013). Dealing with the aftermath of TBI can be complex, as it may involve not only physiological healing but also adjustment to impairments in the control mechanisms for affected psychological, emotional, social, and cognitive functions. Additionally, individuals with TBI may experience complications because of comorbidities associated with the TBI such as post-concussive symptoms, post-traumatic stress disorder, and chronic pain (Risdall & Menon, 2011).

TBI severity is classified as being mild, complicated mild, moderate, or severe and is generally indexed by documenting consciousness changes and/or length of posttraumatic amnesia (PTA; Hart et al., 2016; Herou et al., 2015; McMillan et al., 1996; Williams et al., 2015), or intracranial abnormalities found on neuroimaging in the case of complicated mild TBI (Karr et al., 2020). Although instruments such as the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974), one of the most widely used diagnostic tools for individuals presenting with a head injury (Zuercher et al., 2009), use a three-level classification system (≤ 8 = severe; 9-12 = moderate; 13-15 = mild), the term “mild” may be misleading. Recent studies have substantiated cumulative effects of sustaining multiple mild TBIs such as problems with balance, focus, memory, and pain (CDC, 2015) and persistence of symptoms for at least one year post TBI (McMahon et al., 2014; Theadom et al., 2016; Wäljas et al., 2015). Additionally, symptoms associated with mild TBI may include cognitive impairments such as deficits in executive functioning, memory recall, attention, cognitive flexibility, and processing speed (Barker-Collo, 2015; McCauley et al., 2014; Sivák, 2013).

Moderate to severe TBI often results in noticeable dysfunctions in cognition such as trouble with communication, memory, concentration, learning, and processing. Motor skill deficiencies with balance and muscle weakness may become apparent as consequences of sustaining moderate-to-severe TBI as may deficits in sensory perception (APA, 2013). People with moderate-to-severe TBI may experience more intense mood changes and increased feelings of anxiety, depression, and irritability than they have previously had (Holsinger et al., 2002). Moderate-to-severe TBI symptoms may also manifest as personality changes or increased impulsivity (CDC, 2015).

In the U. S., TBI rates increased by more than 50% in the eight-year period between 2006 and 2014, and there were almost 61,000 deaths (or about 167 per day) related to TBI in 2019 (CDC, 2019). Twenty-two percent of individuals with TBI die within the five years immediately post injury, and overall life expectancy is shortened by nine years (CDC, 2021). Mortality rates increase for those who are older, male, single, unemployed, and have less education (CDC, 2021; Daugherty et al., 2019), and falls were the leading cause of TBI in all ages and of death for people over 75 years old in 2014 (CDC, 2019b; Cuthbert et al., 2015). People with mental health conditions such as schizophrenia, bipolar disorder, and depression are more likely to experience TBI (Dams O'Connor et al., 2016; Malaspina et al., 2001). Fifty-two percent of individuals with TBI get worse or stay the same in the five years following TBI, with only 26% showing improvement during that period (CDC, 2021). Although TBI may once have been thought of as an acute injury, it is increasingly being recognized as a chronic health condition (Corrigan & Hammond, 2013; Masel & DeWitt, 2010) with long-term consequences for many patients such as inability to return to work, repeated hospitalizations, need for assistance in performing routine activities, and misuse of substances (CDC, 2021).

Older Adults Demographics

The U.S. is the third most populous country in the world, with an estimated 332,500,290 people as of April of 2021 (Worldometer, 2021). The number of older adults 65 and above in the U.S. has continued to grow steadily over recent years, increasing from 12.76% of the population in 2009 to 16.21% in 2019, while other population groups have remained at about the same percentage or a little lower over the same time period (Statista, 2020a). Average life expectancy for men in 2017 was 78.6 years and for women was 80 years (Murphy et al., 2018). By 2060, projections are that the over-65 age group will be approximately double what it was in 2018, comprising nearly one-quarter of the U.S. population (Vespa et al., 2020). Furthermore, the number of oldest old (ages 85 and over) is expected to double in the next 15 years and triple by 2060 to approximately 19 million people (Vespa et al., 2020). From middle age onward, there are more women than men in each half decade age category (Statista, 2020b).

Epidemiology of TBI in Older Adults

TBI rates are increasing for older adults, with the greatest number of TBIs incurred by those aged 80 years and older (CDC, 2019b). TBI-related morbidity and mortality rates are highest for older adults when compared to other groups (Dams-O’Connor, 2013; Gardner et al., 2018), with the primary cause for TBI in older adults being falls (Haring, 2015; Harvey & Close, 2012; Mosenthal et al., 2004). As age increases, the likelihood of returning to live alone or at a private residence after a TBI decreases—perhaps because although older adults seem to experience less severe TBIs, rehabilitation takes longer with less improvement in functionality and greater disability after TBI (Cifu et al., 1996; Cuthbert et al., 2015; Mosenthal et al., 2004; Stocchetti et al., 2012; Susman et al., 2002).

The increased risk associated with TBI in older adults is not a recent observation (Vollmer et al., 1991), but explanations as to causality differ. Some theorize that commonly used TBI assessment instruments like the GCS, in addition to having problems with inter-rater reliability and confounds (Zuercher et al., 2009), are not as sensitive for older adults as they are for younger adults, leading to underestimations of TBI severity (Rothweiler et al., 1998; Yap & Chua, 2008). Several studies have demonstrated that older adults with GCS scores in the normal range are among those at highest risk for undetected intracranial lesions (Hawley et al., 2017; Haydel et al., 2000). Neuroinflammatory pattern differences in older versus younger adults have been noted up to six months after a TBI, but it is still unclear as to whether these differences are age- or injury-related (Thompson et al., 2020). Physical health conditions commonly experienced in older age are linked with increased fall risk (Shumway-Cook et al., 2009) and may be responsible for worse outcomes for older adults with TBI (Dams-O'Connor et al., 2016). For example, as cardiovascular illnesses are frequently seen in older adults (CDC, 2021 March), many older adults are placed on prophylactic aspirin therapy to decrease the likelihood of blood clot formation which could lead to serious or even fatal medical conditions like myocardial infarctions or cerebrovascular accidents. While aspirin therapy can be effective in preventing thrombus formation, its antiplatelet properties can also increase the risk of intracranial bleeding subsequent to a fall (Bhattacharya et al., 2016). Others propose that physiological changes related to the aging process (Green et al., 2008; Liu et al., 2017) may be the culprits in the increased vulnerability which accompanies TBI in older adults. As adults age, structural and metabolic changes occur in the brain (Lowe et al., 2019) and throughout the body (e.g., Guirao et al., 2000), resulting in reductions in functional efficiency of the bodily systems. For example, cognitive changes may become apparent in processing speed, memory, and executive functioning (Green et al., 2008; Lowe et al., 2019), and sensorimotor changes are evident in difficulties with eyesight, hearing, balance, and gait (Cheslock & De Jesus, 2021; Guirao et al., 2000; Winter et al., 1990).

Apart from the question of whether age-related health conditions increase the risk of TBI in older adults is the possibility that TBI actually increases vulnerability to developing illnesses like Parkinson's disease (Gardner et al., 2015) and Alzheimer's disease (Ikonomovic et al., 2017), and mental health conditions such as schizophrenia (Molloy et al., 2011) and depression (Jean-Bay, 2000), which could contribute to limited independent function. Although observation of the link between sustaining moderate-to-severe TBI and subsequent development of Alzheimer's disease is not new (e.g., Plassman et al., 2000), ongoing research is elucidating the physiological processes that seem to contribute to the increased risk for developing neurodegenerative diseases such as dementia and Parkinson's disease after TBI (Brett et al., 2021). However, as with much of the research in dementia and TBI to date, findings are not conclusive in proving this association, possibly due to differences in measuring or operationalizing symptoms and outcome variables. For example, Crane and colleagues (2016) found that a history of TBI with loss of consciousness was associated with development of Parkinson's disease and worsening of parkinsonian symptoms and greater numbers of Lewy bodies, but it was not associated with dementia in general, Alzheimer's disease in particular, or the neuronal plaques and tangles often linked with Alzheimer's disease.

Functional Independence and Global Outcomes

The ability of an individual to consistently and autonomously perform basic tasks considered to be necessary for living is termed functional independence (Curzel et al., 2013), and the degree to which functional independence in a person who has experienced TBI can be demonstrated may depend on many factors, including: TBI severity, cognitive and motor limitations, premorbid conditions, access to acute and rehabilitation care, return to employment, age, race/ethnicity, sex, socioeconomic status (SES), and post-TBI social support and engagement. A person's capacity to perform activities of daily living (ADLs) such as feeding, grooming, dressing, toileting, transferring, and mobility and instrumental activities of daily living (IADLs) such as bill paying, cleaning, or preparing meals (Guo & Sapra, 2021) determines how well they can function independently or in other words, how much assistance they require. Ability to function independently in ADLs is associated with acute injury treatment variables such as shorter duration of PTA and time on a ventilator (Sveen et al., 2016) but is also predicted by physical manifestations of the TBI (e.g., motor function) as well as behavioral and memory deficits (Tate & Broe, 1999).

Determination of a person's ability to function independently can be a complex process, and one of the most widely used instruments to assess it is the Functional Independence Measure or FIM (Dodds et al., 1993). The FIM can be used to quantify how much assistance an individual requires overall, and it can be used to delineate disability related to physical (motor) versus cognitive origins (Linacre et al., 1994; Stineman et al., 1996) as well as to monitor change over time (Linacre et al., 1994). In addition to the ADLs covered by the Motor subscale of the FIM, the Cognitive subscale includes functionality in comprehension, expression, social interaction, problem solving, and memory (Dodds et al., 1993). The FIM has a long history of use across many different adult patient populations, treatment and research settings, and clinician types (e.g., Curzel et al., 2013; Ottenbacher et al., 1996; Stineman et al., 1996). For example, the FIM is frequently used in rehabilitation settings and upon discharge from hospital stays (Grey & Kennedy, 1993; Ottenbacher et al., 1996; Prodinger et al., 2017), but it has also been used for such diverse purposes as measuring the effects of the length of stay in intensive care units on resultant disability (Curzel et al., 2013) and for controversial medical decision-making such as whether or not to perform surgery on individuals with spinal cord injuries subsequent to gunshot wounds (McCunniff et al., 2017). In individuals with TBI, the FIM has been supported through adequate validity (Corrigan et al., 1997) and reliability (Bogner et al., 2017) and recommended for use in patient assessment (Pedersen et al., 2018; Stubbs et al., 2014). Additionally, the FIM has been used to measure disability and need for assistance in older adult populations (Ribeiro et al., 2018).

While the FIM Motor and Cognitive subscales examine specific aspects of functionality and may be used with a wide variety of patient populations, the Glasgow Outcome Scale-Extended (GOS-E; Wilson et al., 1998) provides a global overview of ability (whether or not the individual is actually engaged in the action) across consciousness, independence in and out of the home, work, social and leisure participation, relationships with family and friends, and success in returning to a normal life in individuals with brain injury (NDSC, 2021). The GOS-E has been and continues to be used worldwide as a measure of global outcomes after TBI (e.g., Draper et al., 2007; Stålnacke et al., 2019; Stenberg, et al., 2015) and is used in both clinical and research settings (e.g., Bullock et al., 2002; von Steinbuechel et al., 2016). The GOS-E was designed with a structured interview format to address reliability difficulties with the original Glasgow Outcome Scale (Sander, 2002), and has largely achieved this goal, earning adequate reliability and validity ratings (e.g., Bogner et al., 2017; Sander, 2002; Shukla et al., 2011; Wilson et al., 1998; Wilson et al., 2000) and being better at detecting change than the Glasgow Outcome Scale (Levin et al., 2001).

However, there has been discussion that the GOS-E does not adequately measure impairment for lower severity levels of TBI (Ranson et al., 2019). While the GOS-E is considered by some to be the gold standard for rating TBI impairment, others have touted instruments like the Disability Rating Scale (DRS) as more successfully predicting long-term functioning after TBI; however, the DRS and GOS-E have been found to be highly correlated (Eilander et al., 2007; Wilson et al., 2000). The Functional Status Examination (FSE) has also been put forward as a possible improvement on the GOS-E's precision in detecting functional abilities in milder TBI, but more research is needed to validate these findings in larger TBI samples and across different TBI populations (Nelson et al., 2020). One solution to address possible shortcomings of the GOS-E is to combine it with other assessment methods to better capture the multidimensionality of recovery after TBI (Bullock et al., 2002; Nelson et al., 2017; Shukla et al., 2011). As a result, in the current study the FIM Motor, FIM Cognitive, and GOS-E will be used as indices of functional outcomes.

Demographics and Functional Outcomes after TBI

Age. Older adults tend to sustain less severe TBI than younger people, but they have more disability post TBI and are more likely to have a change in where they live after discharge from the hospital (Cuthbert et al., 2015). TBI severity and GCS score can predict function in older adults at discharge from the hospital (Thompson et al., 2012), and level of functioning at that time also predicts long-term functioning (Testa et al., 2005). However, greater age seems to be a factor in poorer outcomes for older adults with TBI, as lower functional independence is predicted by older age (Sendroy-Terrill et al., 2010; Utomo et al., 2009). Not only have older adults shown lower functional independence ratings than younger adults at discharge from the hospital (Marquez de la Plata et al., 2008; Mosenthal et al., 2004) and at six months post discharge (Mosenthal et al., 2004) and more declines in ability five years post injury, but these lower levels of functional independence have occurred despite lower injury ratings (Marquez de la Plata et al., 2008). Older age has also been noted as a consideration in post-acute TBI treatment decisions. Early, intensive, and continuous implementation of rehabilitation treatment is more effective at improving long-term functional outcomes for those with severe TBI than rehabilitation started in the subacute phase (Andelic et al., 2012; Godbolt et al., 2015; Shiel et al., 2001). Discharge from the hospital to a specialized rehabilitation facility has been associated with greater functional independence, and younger people are admitted directly to TBI rehabilitation more frequently than older adults with TBI, despite equivocal injury severity levels (Cuthbert et al., 2011; Sveen et al., 2016).

Sex and Partnered Status. Post-TBI deficits in communication abilities and cognitive and behavioral changes can add to caregiving burden and reduce intimacy and mutuality between spouses (Khan et al., 2003), with some studies showing divorce/separation rates near 50% within the eight years following TBI (Wood & Yurdakul, 1997). Behavioral, emotional, and personality changes seem to be more problematic than physical changes with regard to family caregiver burden (Kreutzer et al., 1992). Depending on the severity of the TBI, its sequelae, and rehabilitation course, older adults who return to their homes may need varying levels of support from informal caregivers such as spouses or other relatives or friends. In the case of older adults with TBI who are partnered, an older spouse may be called upon to provide any needed assistance, which could further complicate recovery depending upon the partner's own age- or health-related limitations. Racial/ethnic minorities with TBI are less likely to be married

(Vanderploeg et al., 2003); however, Arango-Lasprilla and colleagues (2008) found that increased disability on admission (per the Disability Rating Scale) resulted in decreased marriage instability.

Men with moderate to severe TBI have shown better global outcome trajectories over time (Forslund et al., 2019). As women age, they are more likely to live alone, rising from more than one-quarter of women aged 65-74 who live by themselves to over 55% of women aged 85 and older who are on their own (Mather et al., 2019). People who live alone are less likely to be referred to specialized neurorehabilitation after TBI (Jourdan et al., 2012). Older adults who are married when they sustain their TBI are more likely to remain in a stable marriage relationship at two years post injury than younger adults, and women with TBI are more likely to be stably married than are men with TBI across the first two years after TBI (Arango-Lasprilla et al., 2008).

Racial/Ethnic Minority Status. Financial limitations for healthcare access are not the only impediments for racial/ethnic minority individuals with TBI, as minorities may receive less inpatient therapy and less referral to rehabilitation services than their White counterparts (Arango-Lasprilla & Kreutzer, 2010; Asemota et al., 2013; Burnett et al., 2003; Cuthbert et al., 2011; Mellick et al., 2003). Disparities may also be a consequence of reduced access to care, be it due to language barriers, uninsured or underinsured status, transportation difficulties, lack of referrals, or regional unavailability of specialized treatment centers (Arango-Lasprilla & Kreutzer, 2010), with the result that racial/ethnic minorities have worse functional outcomes over time than do Whites (Arango-Lasprilla et al., 2007a; Arango-Lasprilla et al., 2007b). Additionally, personal and cultural experiences such as discrimination and mistrust of the medical community may influence the willingness of racial/ethnic minority members to seek prompt medical attention and engage in rehabilitation activities (Boulware et al., 2003; Casagrande et al., 2007).

Education. Within the last 5 decades, the level of educational attainment of older adults has risen substantially; in 1965, approximately 5% of adults aged 65 and older had bachelor's degrees or higher, whereas in 2018 that number had climbed to 29% (Mather et al., 2019). Educational attainment is an important consideration in older adults with TBI because higher education levels have been linked to better physical and cognitive functioning in numerous studies (e.g., Azouvi et al., 2016; Schonberger et al., 2011; Shumway-Cook et al., 2009). Reasons for education's protective effects have been theorized to include improved cognitive reserve (Levi et al., 2013; Ponsford et al., 2008), greater compensatory capabilities, and a lifestyle more conducive to better brain health (Mather & Scommegna, 2020). In studies specifically examining function after TBI, education level effects have been mixed, with some showing lower educational attainment to be related to poorer functional outcomes (Azouvi et al., 2016; Connelly et al., 2006; Ponsford et al., 2008; & Schonberger et al., 2011) and others finding that education does not significantly predict global outcome trajectories (Forslund et al., 2019).

Insurance. Most older adults in the U.S. have Medicare, but individual plans and corresponding coverage, deductible, and co-pay amounts can differ vastly (CMS, 2021). In a study by Ashley and colleagues (2018), individuals with moderate-to-severe TBI who started rehabilitation three months after the injury (the time period when the most natural recovery is thought to take place) were still showing improvements after 180 days of rehabilitation treatment. Older adults with TBI have slower rehabilitation times (Frankel et al., 2006), so more time spent in rehabilitation may allow for further recovery (Hammond et al., 2019). Individuals with TBI who are discharged from the hospital into a specialized rehabilitation facility have been shown to have more functional independence, but advanced age and payment source factor into decisions regarding where patients go after they are discharged from the hospital (Cuthbert et al., 2011). According to the Centers for Medicare and Medicaid Services, reimbursement for inpatient rehabilitation facility stays is paid by a prospective payment system (PPS), paying fixed amounts for health services rendered (CMS, 2021). After enactment of the PPS, the odds of admission to inpatient rehabilitation facilities post TBI hospitalization decreased by 16% (Hoffman et al., 2012).

According to a U.S. Census Bureau survey, the poverty rate for older adults in general is about 9%, but it is markedly higher for older Latinos (17%) and African Americans (19%) than it is for Whites (7%). These disparities can impact rehabilitation and recovery, as racial/ethnic minority group members with TBI have less health insurance coverage (Shafi et al., 2007) and age, sex, race/ethnicity, and payment source all influence decisions to discharge from acute care to a rehabilitation center (Cuthbert et al., 2011). Conclusions differ as to whether individuals with no insurance or public insurance are less likely (Asemota et al., 2013; Heffernan et al., 2011; Hoffman et al., 2012; McQuiston et al., 2016) or equally likely to be discharged to a rehabilitation facility; however, those who are uninsured have poorer long-term functional outcomes (Shafi et al., 2007) and are more likely to die while hospitalized than individuals with private insurance (Heffernan et al., 2011; McQuiston et al., 2016). Facilities which accept Medicare payment may discharge patients with suboptimal functional independence because of fixed reimbursement rates which may not cover actual rehabilitation costs (Hoffman et al., 2003).

Employment. Employability after a TBI involves factors such as physical manifestations of the TBI (e.g., motor function) as well as behavioral and memory deficits (Tate & Broe, 1999).

Gary and colleagues (2009) found that age, disability status at hospital discharge, length of hospitalization and rehabilitation, employment status before TBI, sex, education, partnered status, and cause of TBI all predicted post-TBI employment. With people living longer, many older adults are staying in the workforce beyond the traditional ages of retirement at 62 or 65. The U.S. Bureau of Labor Statistics estimates that by 2024 one-quarter of American employees will comprise adults aged 55 and older, with 13 million 65 and older and a labor force increase of 86% for those 75 and older (Toossi & Torpey, 2017). Aside from obvious financial implications for older workers, cognitive function remains higher for those who continue in the workforce compared to those who stay retired (Lee et al., 2019). People who receive family support post-TBI lessen their debility and increase their chances of returning to work, which in turn raises their quality of life and their functional independence (Webb et al., 1995). Although almost 50% of those who experience a TBI are retired, with only 3.2% of the group aged 80 and above employed immediately before the TBI (Cuthbert et al., 2015), these numbers are likely to change to reflect the increasing number of older adults who are gainfully employed into their 70s and 80s. Older adults are more likely to have changes in their employment status post TBI and therefore be less likely to be physically and financially independent one to two years post injury (Testa et al., 2005). Racial/ethnic minorities have worse employment outcomes (steadily competitively employed) over the five years post-TBI than do racial/ethnic majority members (Arango-Lasprilla et al., 2010; Gary et al., 2009).

Social Participation. Social interactions may be limited post-TBI by cognitive, functional, behavioral, socioemotional, or physical ramifications such as an inability or unwillingness to take part in activities that involve people or places outside the family or home like working, driving, attending social events, or engaging in hobbies. Reasons for narrowing social roles and interactions may be primary effects from the TBI which impair motivation or ability to be with others (Tate et al., 1989) and psychosocial contributors such as behavioral regulation and cognitive changes (Tate & Broe, 1999). Examples are feeling weak or fatigued, having trouble communicating or concentrating, loss of interest in previously enjoyed activities, fear of others' reactions to them, and decreased access or opportunities to participate in social activities (Khan et al., 2003). Some individuals may choose to self-isolate post TBI because they may be aware of distressing or embarrassing changes in themselves in impulsivity, self-centeredness, disinhibition, social skills, apathy (Khan et al., 2003), and speed (Nochi, 1998), and they may then constrain their social participation to include only those within the immediate social circle. However, if an individual is unaware of problematic changes in behavior after TBI, they could be puzzled and frustrated by negative interactions with others and therefore limit their social involvement. Individuals who have experienced a TBI often feel unnoticed and trapped by the consequences they are experiencing after the TBI (Chamberlain, 2006). Members of racial/ethnic minority groups have lower levels of social integration across living situations, interaction with friends, and participation in leisure activities for at least one year after TBI (Arango-Lasprilla et al., 2010). Reduced social participation is problematic because physical recovery, mental health, and overall quality of life is better with continued engagement in social roles (Bay et al., 2002; Juengst et al., 2015; McClean et al., 2016).

Pre-Existing Conditions. A wide variety of pre-existing health conditions have been found to reduce the degree of functional recovery post TBI, especially in men and in older women (Chan et al., 2020). Older age increases the risk of developing chronic illnesses, and over half of older adults in the U.S. have at least one serious health condition such as arthritis, diabetes, hypertension, or cardiovascular disease (CDC, 2020; He et al., 2018; NCO, 2021), or some type of disability (BLS, 2019) which may limit their ability to function (e.g., learning, dressing, going out of the home, working) after experiencing a TBI (Dahdah et al., 2016). Substance misuse has been linked to TBI as both a cause and an outcome, and systematic reviews have found a history of alcohol or drug misuse in 1/3 to 2/3 of those with TBI (Corrigan, 1995; Parry-Jones et al., 2011; Kreutzer et al., 1991). Findings show generally worse outcomes after TBI for those with a history of alcohol misuse prior to their TBI (Corrigan, 1995). Additionally, those with co-occurring substance use disorders and mental health conditions have a high incidence of incurring TBIs (McHugo et al., 2017), as do individuals who have had treatment for psychological conditions (outpatient or inpatient) alone (Liao et al., 2012; Vassallo et al., 2007). Individuals with a history of psychiatric treatment have higher risk for developing PTSD and major depressive disorder (Stein et al., 2019) as well as anxiety and depressive disorders (Scholten et al., 2016) after TBI.

Current Study

Although functional independence outcomes after TBI have been examined in various studies (e.g., Seagly et al., 2018; Tate & Broe, 1999), research on the older adult population with TBI has been relatively sparse. Lifespan is increasing worldwide (WHO, 2019), and as a result the proportion and number of older adults is increasing steadily (Worldometer, 2020). Morbidity and mortality rates are much higher for older adults after TBI than they are for younger adults (Dams-O'Connor, 2013; Gardner et al., 2018), and older adults have worse recovery outcomes even when injury severity is milder (Stocchetti et al., 2012; Susman et al., 2002). As the risk for incurring a TBI increases with age (CDC, 2019b; Thompson et al., 2006), the greater number of older adults alone makes examination of factors contributing to poorer functional independence outcomes an important area of study. Older adults with TBI have a smaller chance of returning to independent living or employment after TBI (Cuthbert et al., 2015; Testa et al., 2005), and their increased need for post TBI assistance could have serious repercussions for additional demands imposed on healthcare systems, health insurance systems, local and national economies, and family and social systems. With the higher risks and reduced outcomes for older adults with TBI, it is important to understand what sociodemographic and injury severity characteristics predict functional independence outcomes over time for this population in order to bring awareness of factors which elevate risk and to mitigate those risks as much as possible and as early as possible. As a result, the purpose of the current study is to examine sociodemographic and injury characteristics as predictors of functional independence trajectories in older adults with TBI across the 10 years after injury. Based on the previous literature, it is hypothesized that:

H1. There will be initial improvement in FIM Motor, FIM Cognitive, and GOS-E scores with a plateau in improvement by the 2- or 5-year time points. Individuals with moderate-to-severe TBI have shown improved functional outcomes over time but with a plateau effect at 3 months for FIM scores and at 12 months for GOS-E scores (Sandhaug et al., 2015). Given that older adults recover more slowly from TBI (Frankel et al., 2006; Hammond et al., 2019), it is hypothesized that this plateau will occur slightly later in the trajectory.

H2. Older age at the time of injury will be associated with lower functional independence over time. Previous research has found that individuals who were younger at the time of injury had better GOS-E trajectories over time (Forslund et al., 2017) and that lower functional independence is predicted by older age (Sendroy-Terrill et al., 2010; Utomo et al., 2009).

H3. Individuals with sociodemographic risk factors, including: women, underrepresented minorities, unpartnered individuals, and those with public insurance, lower educational levels, unemployed at time of injury, and with pre-existing health conditions, will have lower functional independence trajectories after TBI.

Men with moderate to severe TBI have shown better global outcome trajectories over time (Forslund et al., 2019). Individuals who live alone have been found to receive fewer referrals to specialized rehabilitation (Jourdan et al., 2012), potentially impacting their degree of functional independence recovery. A marital relationship can be protective against physiologically harmful processes, especially in men (Wong & Waite, 2015).

Underrepresented racial/ethnic minority group members (e.g., Black, Hispanic, or Native American vs. White or Asian) may experience disparities with regard to overall availability and access to care (Arango-Lasprilla & Kreutzer, 2010; Asemota et al., 2013; Heffernan et al., 2011), as do Blacks and Hispanics (Arango-Lasprilla et al., 2007a; Arango-Lasprilla et al., 2007b; Gary et al., 2009) and non-Caucasians (Heffernan et al., 2011) in general.

Higher education levels are associated with better physical and cognitive functioning in more studies than not (e.g., Azouvi et al., 2016; Forslund et al., 2019; Schonberger et al., 2011; Shumway-Cook et al., 2009).

TBI may have long-lasting effects (CDC, 2015; CDC, 2019; APA, 2013), and recovery may be prolonged. Because older adults tend to take longer to make rehabilitative progress (Frankel et al., 2006), they may require more time in rehabilitation, but insufficient Medicare reimbursement may prompt facilities to discharge individuals before they reach optimal rehabilitative status (Hoffman et al., 2003).

In 2018, almost 25% of men and 16% of women 65 or older continued to be employed (Mather et al., 2019). Being employed at the time of injury is a predictor of post-TBI employment (Gary et al., 2009) as well as lower disability trajectories over time (Forslund et al., 2017).

The majority of older adults have at least one chronic condition (He et al., 2018), and these pre-existing mental and/or physical health conditions may reduce functional independence recovery post TBI (Chan et al., 2020).

H4. Individuals with more severe TBI (as measured by length of PTA) will have lower functional independence over time. Longer PTA has been robustly shown to predict reduced global outcomes over time (Forslund et al., 2017; Forslund et al., 2019).

Chapter 2: Method

Procedure

A request for permission to use public data from the TBIMS National Database to conduct this study was submitted to the TBIMS National Data and Statistical Center and approved. The current study conducted secondary analyses of data collected as part of the TBIMS program. The TBIMS database is the largest longitudinal study of TBI in the world and comprises data collected from 16 multidisciplinary rehabilitation medical centers and 3 follow-up centers nationwide. TBIMS data collection began in 1987 and is ongoing. Currently, there is information covering pre-injury, acute care, rehabilitation, and longitudinal outcomes on over 18,000 individuals with TBI in the TBIMS database. Data are collected via medical record abstraction, data collection forms, examination of patients, and interviews with patients and family members. Follow-up interviews are conducted by phone, in person, or by mail with the patient or their proxy at years 1, 2, 5, 10, and every 5 years thereafter, although only data from the first 10 years will be used for the current study. The U.S. Department of Health and Human

Services funds the TBIMS program through the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR) (MSKTC, 2020; NDSC, March 2017).

Participants

Criteria for inclusion in the TBIMS database are complicated mild or moderate-to-severe TBI, admission to a TBIMS emergency department within 72 hours of sustaining the TBI, age of at least 16 years, acute care and inpatient rehabilitation in the TBIMS hospitals, and informed consent by patient, family member, or guardian. Adults aged 60 or older made up 20% of the more than 16,500 TBIMS participants. Racial/ethnic minorities comprised 34% of TBIMS participants (Black: 18%; Hispanic 11%; Asian 3%; Others 2%), 74% were male, mean length of PTA was 23 days, and 36% of participants had their rehabilitation costs paid by Medicare or Medicaid. Most participants lived with parents (22%) or a partner (40%), and 60% were employed at the time they incurred the TBI. (TBIMS, 2018).

Data from participants in the TBIMS national database who sustained a TBI at age 60 and older and had at least one FIM Motor, FIM Cognitive, and GOS-E score at one follow-up time point (data were collected at one year, two years, five years, and ten years post TBI) were included in the present study. In the current sample, 2,459 older adults met these inclusion criteria. At the time of injury the mean age of the current study sample was 71.67 years. Racial/ethnic minorities comprised 23% of current sample participants (Black: 12%; Hispanic: 7%; Asian: 3%; Native American: 0.3%; Other: 1%), 63% were male, and 27% were employed (45% were retired). The majority of sample participants sustained their TBI from a fall (64%). Most sample participants were living with a spouse or significant other (58%) and did not have private insurance (65.8%). The mean length of PTA for the current sample was 17 days, and most participants were discharged to a private residence after rehabilitation (73%).Demographic data are presented in Table 1.

Table 1

Sample Characteristics

Characteristics	(*N* = 2,459)
Age, *M* (*SD*)	71.67 (8.63)
Sex, *n* (%)	
Male	1554 (63.2)
Female	905 (36.8)
Race/Ethnicity, *n* (%)	
White/Asian/Pacific Islander	1980 (80.5)
Underrepresented Minority	454 (18.5)
Education, *M* (*SD)*	12.13 (3.67)
Relationship Status *n* (%)	
Partnered	1387 (56.4)
Unpartnered	1071 (43.6)
Insurance	
Private	836 (34)
Other	1607 (65.4)
Employment at Injury, *n* (%)	
Competitively Employed	668 (27.2)
Not Employed	1620 (65.9)
History of Substance Use Disorder, *n* (%)	
No	1913 (77.8)
Yes	386 (15.7)
Pre-TBI Health, *n* (%)	
Limitations to Learning	280 (11.4)
Limitations to Dressing	111 (4.5)
Limitations to Working	255 (10.4)
Limitations to Going Out of the Home	214 (8.7)
History of Mental Illness Treatment	292 (11.9)
Days in Posttraumatic Amnesia, *M (SD)*	1.32 (0.85)
Cause of TBI, *n* (%)	
Fall	1581 (64.4)
Motor Vehicle Accident	571 (23.3)
Pedestrian	156 (6.4)
Violence	91 (3.6)
Other	60 (2.3)

Residence after Rehabilitation, *n* (%)	
Private Home	1778 (72.5)
Nursing Home	517 (21.1)
Adult Home	63 (2.6)
Hospital: Acute Care	54 (2.2)
Hospital: Rehabilitation	20 (0.8)
Other	22 (0.8)

Measures

Sociodemographic Characteristics

Age. Age was reported at the time of injury, and participants ranged from 60 years to more than 89 years (data were not collected on specific age past age 89 for confidentiality purposes, and those above age 89 were recoded as age 89).

Sex. Sex was reported as male or female at the time of injury.

Race/ethnicity. Race/ethnicity was dichotomized as White and Asian/Pacific Islander or underrepresented minority (Black, Native American, Hispanic Origin, and Other).

Education. Level of education was noted in years from 0 to 19.

Partnered status. Participants were considered partnered if they were married or cohabiting at the time of injury.

Insurance. Insurance was categorized as either private or other.

Employment status. Employment status was recorded for the month before injury, and participants were considered employed if they were competitively employed, whether legally or illegally.

Substance use. Participants were divided into those with a history of substance use disorder and those without such a history.

Pre-TBI Health. Participants' physical and mental health pre-TBI was measured by endorsement of limitations to learning, dressing, working, going out of the house, or by a history of treatment for mental illness.

Injury Severity

Injury severity was measured by length of PTA. An individual was deemed to have emerged from PTA on the first day when there were two consecutive days where scores were greater than the cutoff with not more than two full days between measurements. If an individual was discharged from acute rehabilitation while still in PTA, for the purposes of this study their PTA score was coded as length of hospital stay (days) plus one, as is the convention in the TBIMS database. When language function was restricted, PTA was determined by the judgment of a qualified medical professional. Otherwise, it was determined by using one of the following instruments and its corresponding cutoff score: Galveston Orientation and Amnesia Test (GOAT) (Levin et al., 1979) scores greater than 75; revised GOAT scores greater than 11; Orientation Log (O-Log) (Jackson et al., 1998) scores of 25 or greater; O-Log Non-Verbal version scores of 8 or greater. TBI severity is classified as Mild if PTA is 0-1 day, Moderate if PTA is 2-7 days, and Severe if PTA is greater than 7 days (Cho & Jang, 2021; O'Neil et al., 2013).

Functional Independence

FIM. The FIM is an 18-item measure which rates an individual's ability to function independently across cognitive and motor domains. The 5 cognitive items assess functional independence in comprehension, expression, social interaction, problem solving, and memory, and the 13 motor items assessed are eating, grooming, bathing, dressing (upper and lower body), toileting and bladder/bowel management, transfers between bed and chair and to toilet and shower, locomotion, and stair climbing. The items are scored on a 1-7 scale with a possible total score range from 18 to 126. Higher scores indicate greater independent functioning on the task associated with the item, and lower scores indicate greater need for assistance from another person: values of 1 signify "needs total assistance" and values of 7 signify "has complete independence." The scores of the 13 Motor items are summed for the FIM Motor scores and the 5 Cognitive item scores are summed for the FIM Cognitive scores. The FIM total scores are the sums of the FIM Cognitive and FIM Motor subscale scores, and FIM total scores at discharge and at each followup timepoint are the scores used in the current study. Multiple studies have demonstrated the reliability and validity of the FIM over many years (e.g., Stineman et al., 1996), and in individuals with TBI, the FIM has been supported through adequate validity (Corrigan et al., 1997) and reliability (Bogner et al., 2017) and recommended for use in patient assessment (Pedersen et al., 2018; Stubbs et al., 2014). Additionally, the FIM has been used to measure disability and need for assistance in older adult populations (Ribeiro et al., 2018).

GOS-E. The GOS-E uses a structured interview to assess functional capability in individuals in 7 broad domains: consciousness, independence in and out of the home, work, social and leisure life, family and friend relationships, and return to normal life activities. Answers to the GOS-E interview are provided by the individual with TBI or another informant or source to achieve the most accurate rating (Sander, 2001). Overall outcome ratings are based on the response in the lowest outcome category: 1 = dead; 2 = vegetative state; 3 = lower severe disability; 4 = upper severe disability; 5 = lower moderate disability; 6 = upper moderate disability; 7 = lower good recovery; 8 = upper good recovery (Wilson et al., 1998). The GOS-E Total scores will be used in the current study. The GOS-E has earned adequate validity and reliability ratings in multiple studies (e.g., Bogner et al., 2017; Sander, 2002; Shukla et al., 2011; Wilson et al., 1998; Wilson et al., 2000).

Data Analyses

All analyses were conducted using IBM SPSS Statistics version 27. As over the 10-year follow-up period many participants had missing data, Little's missing completely at random (MCAR) test was performed on the data, and full information maximum likelihood (FIML) estimation was used to account for missing values, allowing retention of all participants meeting inclusion criteria. Dichotomous variables were given a reference point of 0, and continuous variables were centered around their means to reduce multicollinearity.

To examine trajectories of functional independence across the 10 years after TBI in older adults, several series of hierarchical linear models (HLMs) were run, one series for each of the three outcome variables. For each series, an unconditional growth model was run first with the successive additions of $time^2$ and $time^3$ to determine whether linear, quadratic, or cubic time models best depicted functional independence movement over time. -2 log likelihoods (-2LLs) were calculated and compared for each model, with a drop of 3.84 chi-squared points reflecting a statistically significant improvement over the previous model.

HLM was then used to examine baseline predictors of FIM Motor, FIM Cognitive, and GOS-E trajectories among older adults across 1, 2, 5, and 10 years after TBI. Predictors were entered simultaneously as fixed effects after being centered or given a reference point of 0, along with time (and with $time^2$ or $time^3$ as applicable). Each main HLM determined whether linear outcome trajectories across the four time points were predicted by baseline sociodemographic and injury severity characteristics of: time (coded as 0 [1 year], 1 [2 years], 4 [5 years], and 9 [10 years]); age; sex (coded as 0 = female, 1 = male); race/ethnicity (coded as 0 =

White/Asian/Pacific Islander, 1 = underrepresented minority); education level; relationship status (coded as 0 = unpartnered, 1 = partnered); insurance type (coded as 0 = other, 1 = private); employment status at time of injury (coded as 0 = not employed, 1 = employed); history of substance use disorder (coded as 0 = no, 1 = yes); pre-TBI functional limitations in learning, dressing, working, or going out of the home (coded as 0 = no limitations, 1 = limitations); history of mental health treatment (coded as 0 = no, 1 = yes); and days in posttraumatic amnesia (PTA, with discharge while still in PTA being recoded as the number of days in TBI care +1). In order to test potential differential effects of the predictors over time (e.g., differences in slope as a function of the predictor), follow-up HLMs included each of the previously significant predictors from the first full model, time (and with $time^2$ or $time^3$ as applicable), and the interaction terms between time terms and the previously significant predictor.

Results

Little's MCAR Tests

Given that all three Little's MCAR tests were statistically significant (FIM Motor: χ^2 (28) = 166.21, p < .001; FIM Cognitive: χ^2 (28) = 150.81, p < .001; and GOS-E: χ^2 (28) = 201.49, p < .001), reflecting differential attrition over time, FIML was used to account for missing data in the trajectory analyses. For degree of missingness of FIM Motor, FIM Cognitive, and GOS-E scores at follow-up time points, see Table 2.

Table 2

Percentage of Data Present at Each Follow-up Time Point

Data Present %	Year 1	Year 2	Year 5	Year 10
FIM Motor	92.2	72.7	37.9	12.6
FIM Cognitive	92.9	73.6	38.4	12.9
GOS-E	91.1	78.4	50.3	20.9

In order to avoid biasing figures by only graphing the outcome scores of participants with data present, the expectation maximization algorithm was used to impute missing values that then were used to calculate overall means to be presented in the figures.

FIM Motor

The -2LL of the initial model with linear time was 43,787.53; the -2LL of the model with the addition of quadratic time was 43,787.53; and the -2LL of the model with the addition of cubic time was 43,787.23. Each successive addition of a time product term did not result in a -2LL decrease of more than 3.84 chi-square points from the previous models, which suggested that linear (straight line) movement of FIM Motor trajectories was the best fit for the data.

In the main HLM, FIM Motor scores decreased over time. The unstandardized *b*-weights and *p*-values for this HLM appear in Table 3.

Table 3

Fixed Effects

	FIM Motor		FIM Cog.		GOS-E	
Characteristics	*b*-weight	*p*-value	*b*-weight	*p*-value	*b*-weight	*p*-value
Intercept	80.24	<.001	30.77	<.001	5.86	<.001
Time	-.79	<.001	-.24	<.001	-.30	<.001
Time*Time	--	--	--	--	-.003	.882
Age	-.36	<.001	-.11	<.001	-.05	<.001
Sex	.87	.329	-.17	.574	-.21	.041
Race/Ethnicity	-4.33	<.001	-1.07	.006	-.44	.001
Education	.34	.006	.16	<.001	.05	.001
Relationship Status	.20	.816	.20	.498	.14	.180
Insurance	-.86	.374	-30	.371	-.06	.601
Employment at Time of Injury	2.76	.007	.72	.041	.06	.637
History of Substance Use Disorder	-.21	.852	-.21	.589	.26	.045
Pre-TBI Health Limitations						
Learning	-2.76	.03	-2.70	<.001	-.37	.012
Dressing	-6.37	.005	-1.08	.164	-.25	.347

Working	-1.18	.409	-.44	.377	-.45	.008
Going Out of Home	-8.66	<.001	-2.14	<.001	-.77	<.001
Mental Illness Treatment	-.94	.382	-.25	.504	-.04	.768
Days in Posttraumatic Amnesia	-3.35	<.001	-1.51	<.001	-.39	<.001

Lower FIM Motor trajectories were seen among participants who had been older at baseline (Figure 1); were members of an underrepresented racial/ethnic minority group (Figure 2); had lower educational attainment (Figure 3); had been unemployed at injury (Figure 4); had pre-TBI functional limitations in learning (Figure 5), dressing (Figure 6), or going out of the home (Figure 7); and had greater injury severity based on length of PTA (Figure 8).

Figure 1

Main Effect of Age on FIM Motor Trajectories

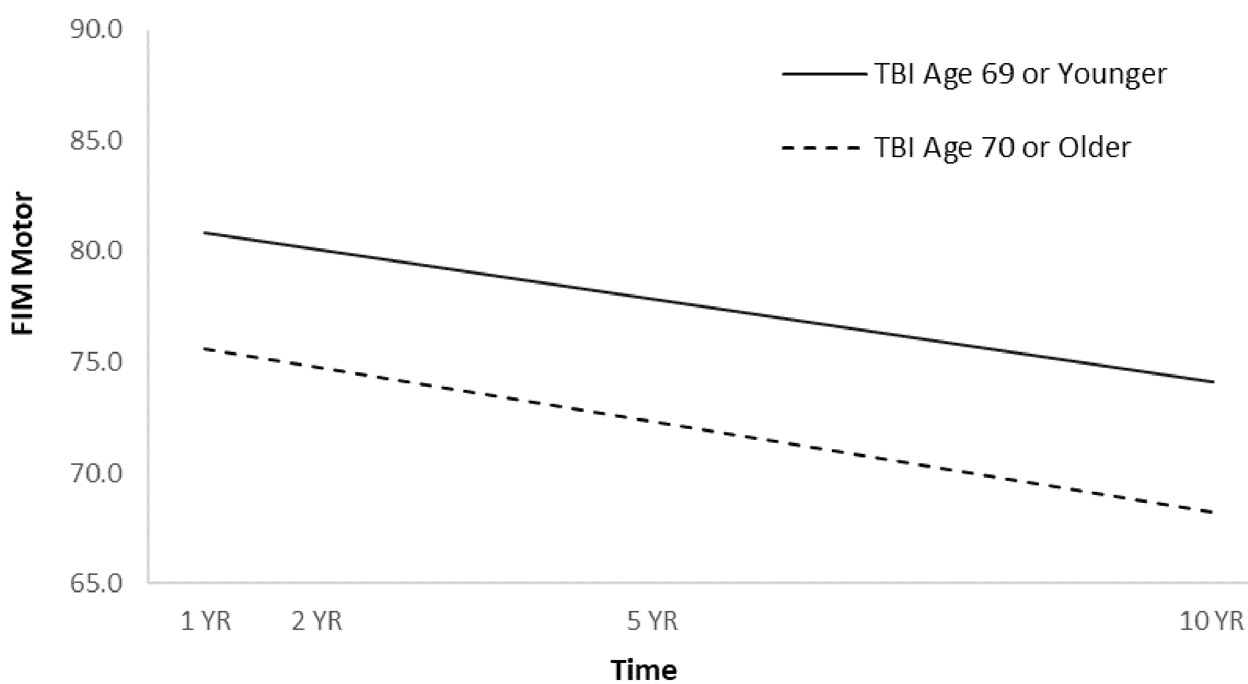


Figure 2

Main Effect of Race/Ethnicity on FIM Motor Trajectories

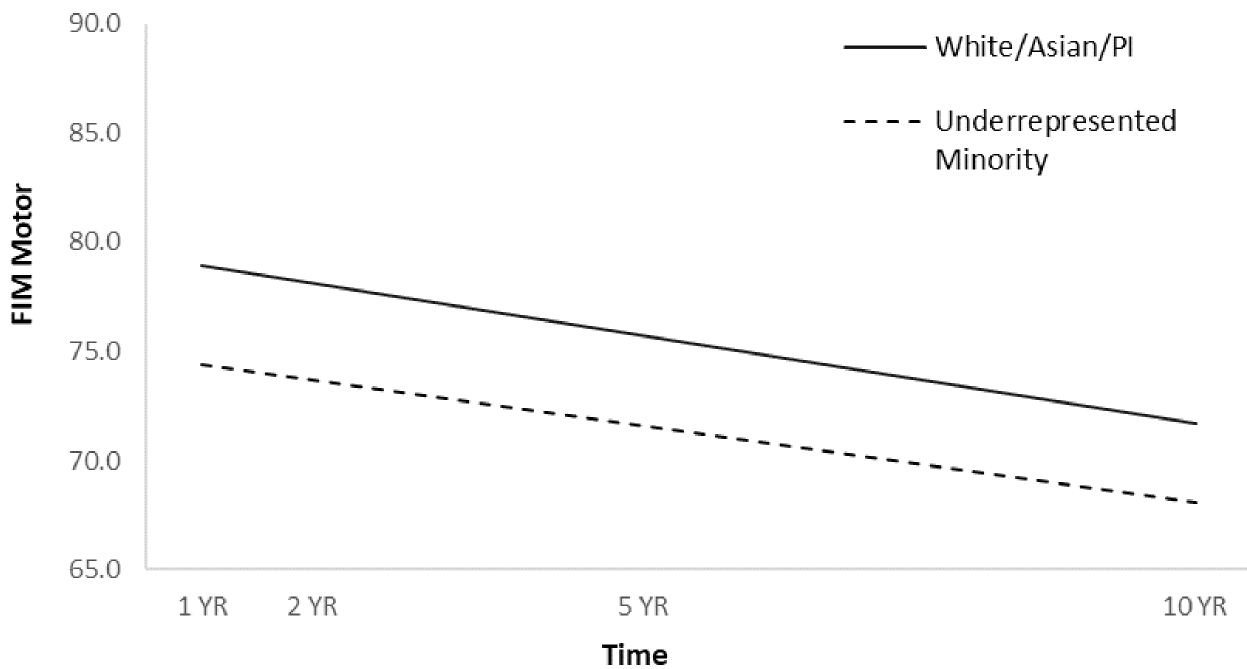


Figure 3

Main Effect of Education on FIM Motor Trajectories

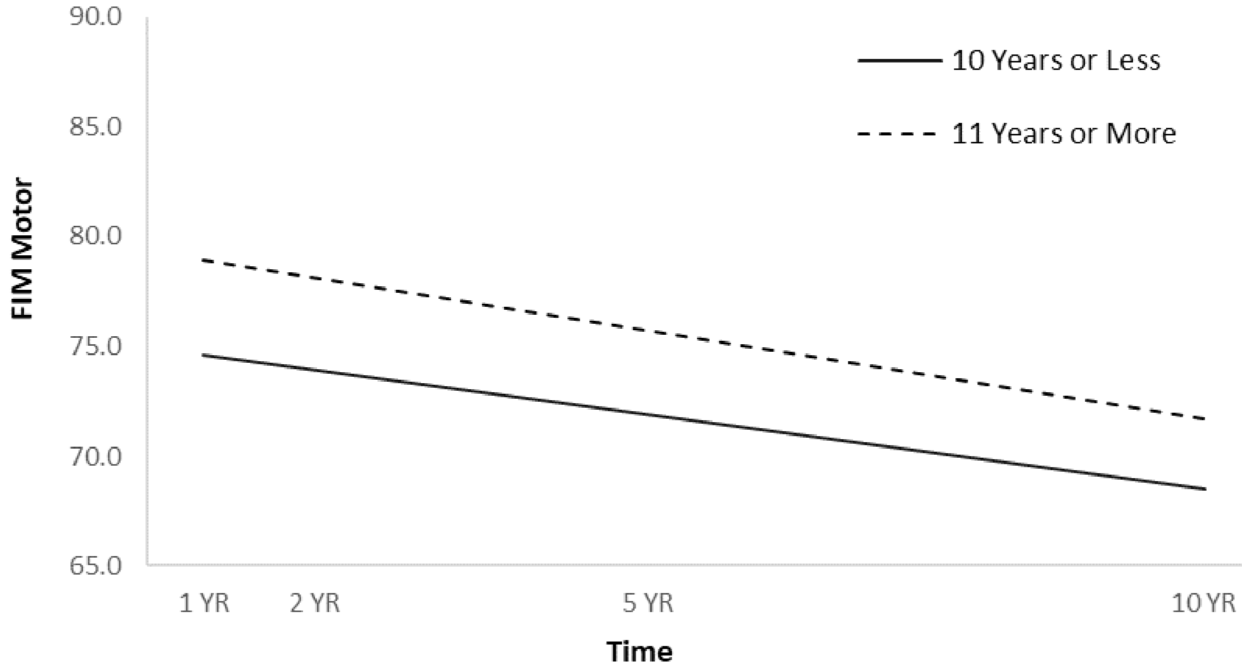


Figure 4

Main Effect of Employment at Injury on FIM Motor Trajectories

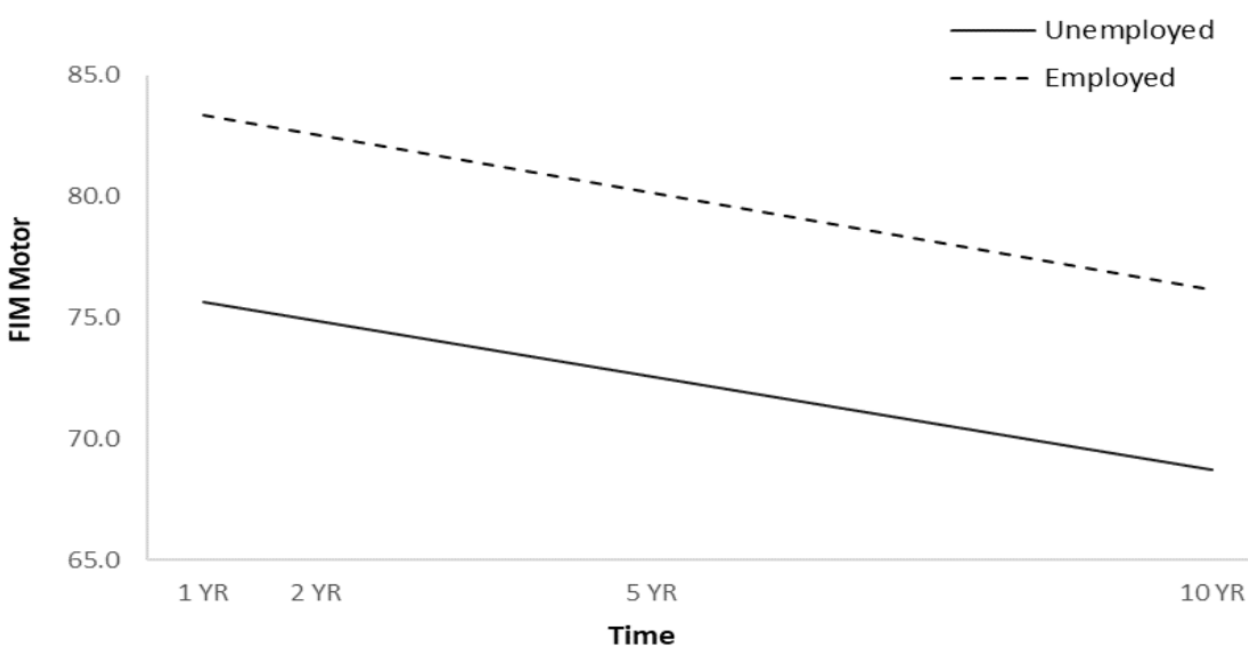


Figure 5

Main Effect of Pre-TBI Limitations in Learning on FIM Motor Trajectories

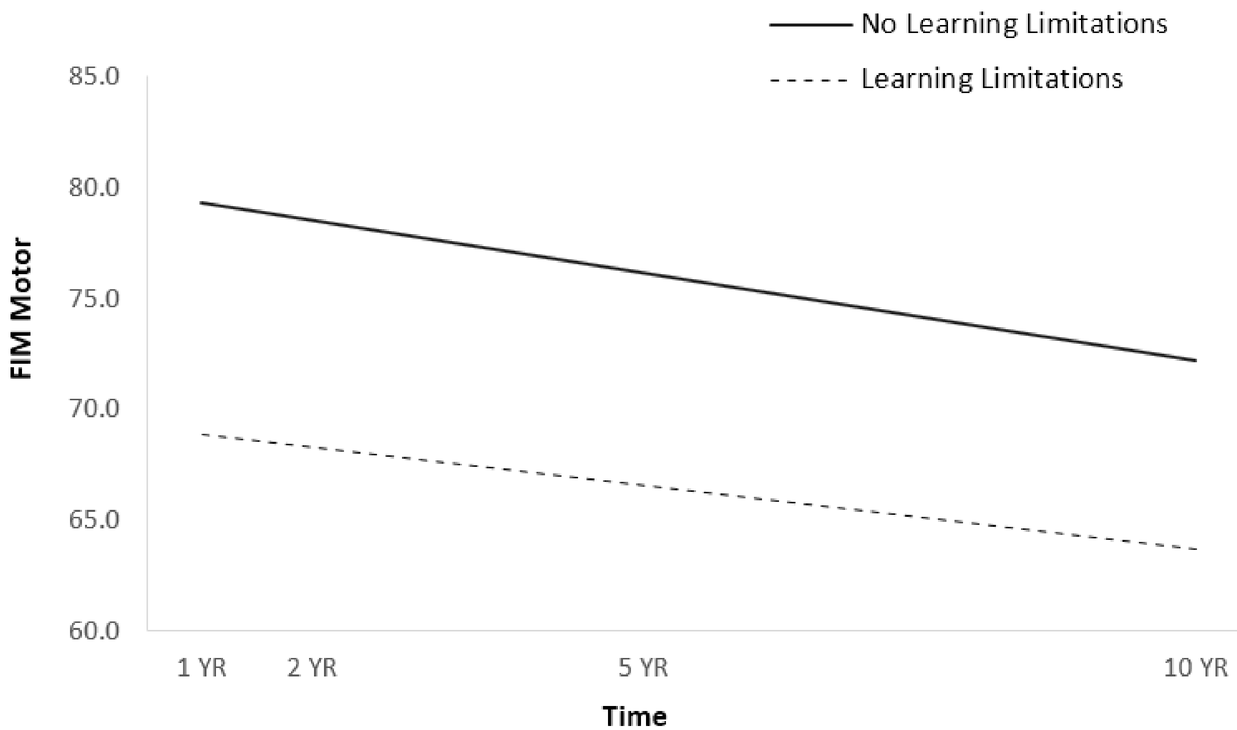


Figure 6

Main Effect of Pre-TBI Limitations in Dressing on FIM Motor Trajectories

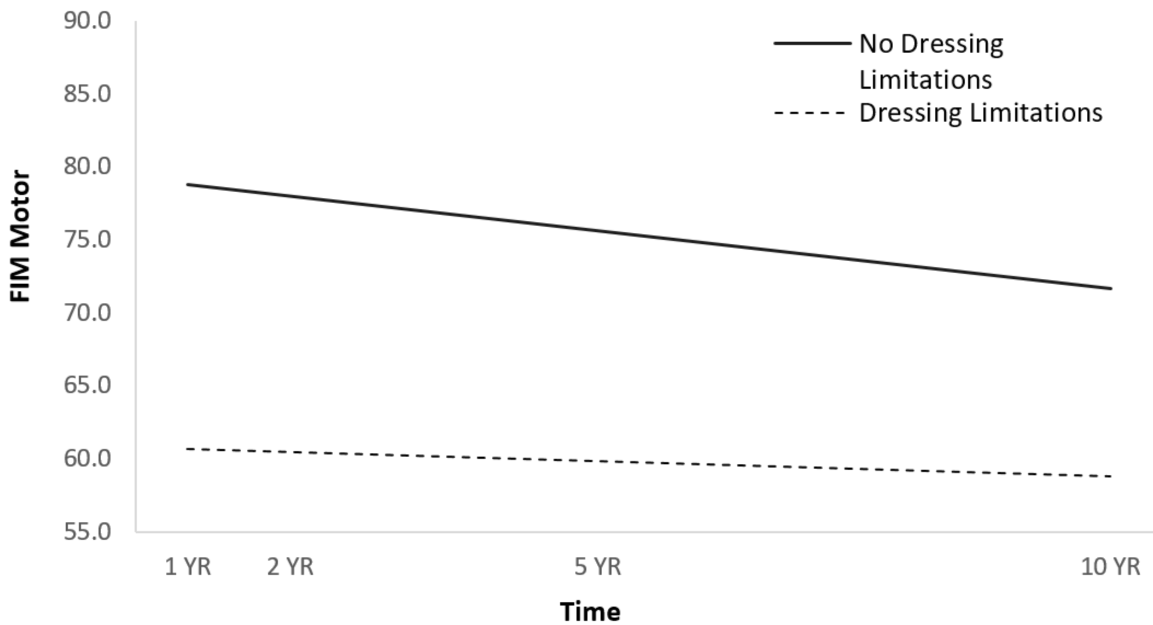


Figure 7

Main Effect of Pre-TBI Limitations in Going out of the Home on FIM Motor Trajectories

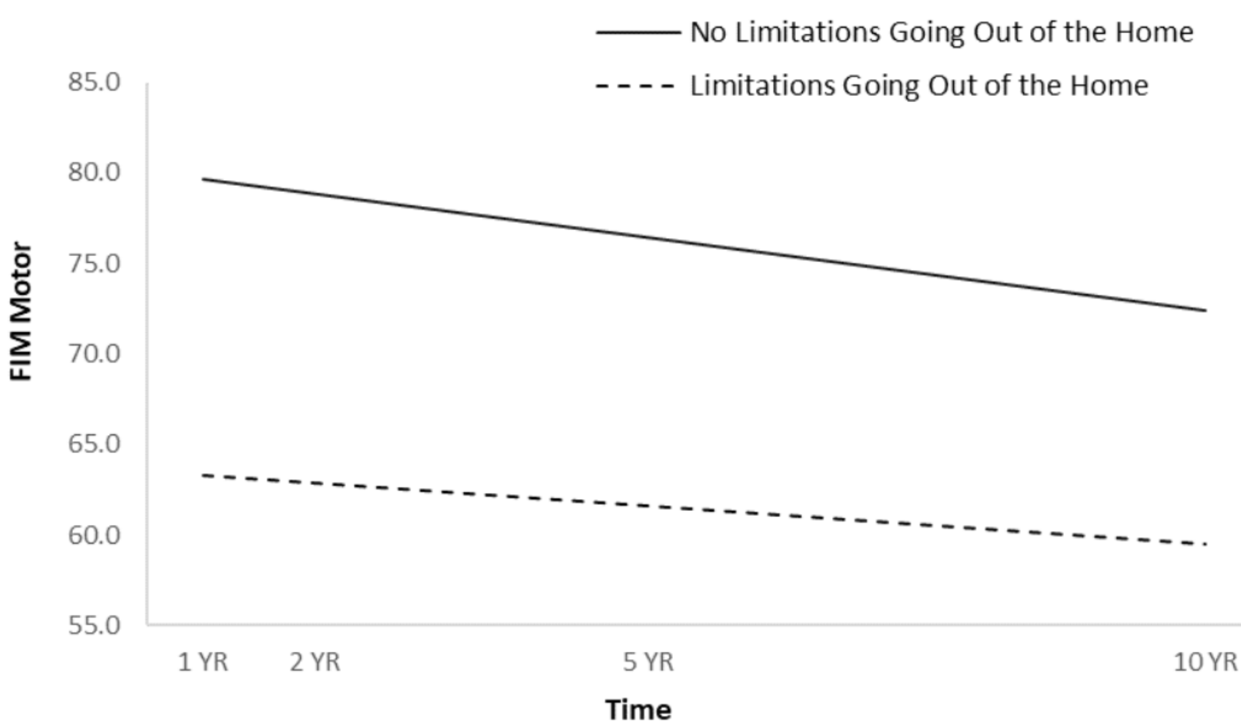
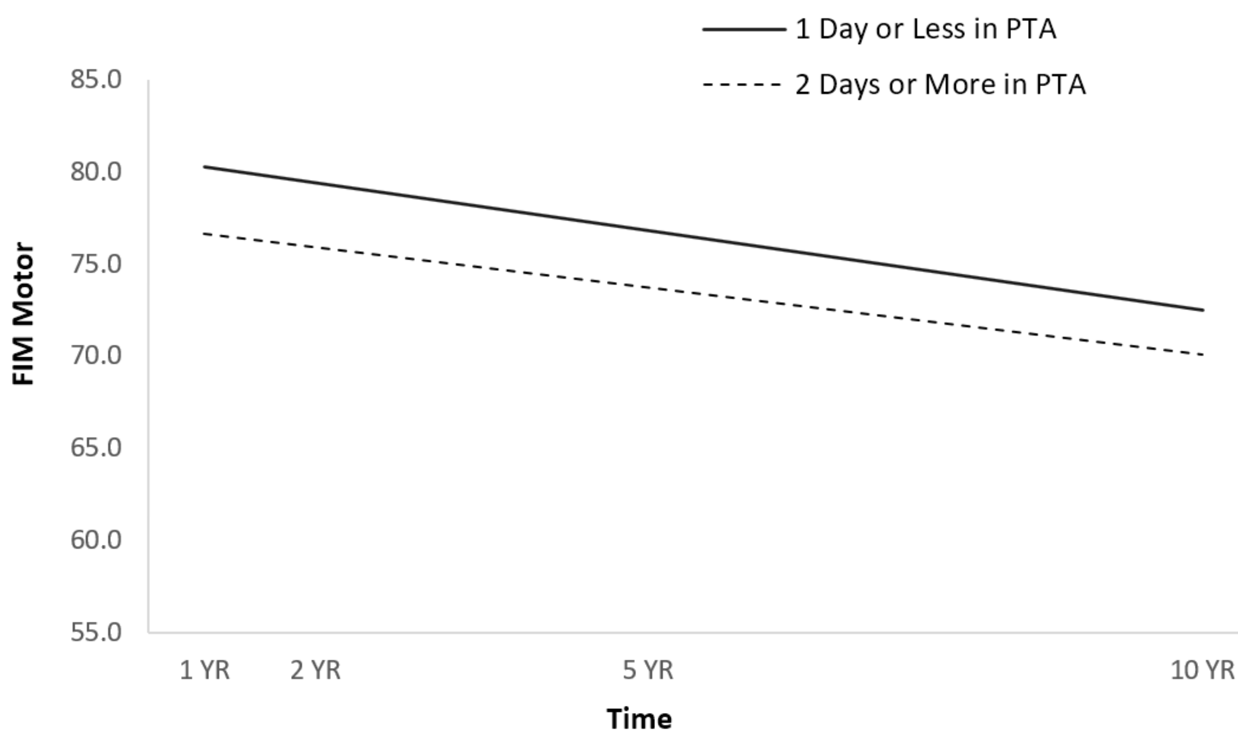


Figure 8

Main Effect of Time in Posttraumatic Amnesia (PTA) on FIM Motor Trajectories



Follow-up HLMs examined whether linear trajectories of FIM Motor could be predicted by the previously significant predictors and their interactions with time (Table 4). There were

Table 4

Significant Interactions in Predictors over Time

Interaction Effects	*b*-weight	*p*-value
FIM Motor		
Time * Age	-.086	<.001
Time * Employment	.703	<.001
Time * Pre-TBI Learning Limitations	-.766	.010
FIM Cognitive		
Time * Age	-.027	<.001
Time * Employment	.286	<.001
Time * Pre-TBI Limitations in Going Out of the Home	-.245	.047
Time * Injury Severity	.082	.008
GOS-E		
Time * Time * Age	.001	.002
Time * Time * Race/Ethnicity	.016	.041
Time * Time * Pre-TBI Limitations in Working	.049	.001

Time * Time * Pre-TBI Limitations in Going Out of the Home	.048	<.001

significant interactions for time*age, time*employment status at baseline, and time*pre-TBI learning limitations, suggesting differential change over time in motor functional independence as a function of these characteristics. The significant time*age interaction suggested that FIM Motor scores decreased over time for all older adults with TBI, but the decrease was steeper for those who had sustained their TBI at an older age (Figure 1). The significant time*employment status interaction suggested that FIM Motor scores decreased over time for those who had been employed at the time of injury as well as for those who had been unemployed at the time of injury, with scores of those who had been employed decreasing at a slightly faster rate (Figure 4). However, the visual interaction effect in the figure was barely detectable so this interpretation may be unreliable and will not be interpreted further. The significant time*pre-injury learning limitations interaction suggested that FIM Motor scores decreased over time, with scores decreasing at a slightly faster rate for those who had had no pre-TBI learning limitations (Figure 5).

FIM Cognitive

The -2LL of the initial model with linear time was 33,407.76; the -2LL of the model with the addition of quadratic time was 33,407.73; and the -2LL of the model with the addition of cubic time was 33,407.68. Each successive addition of a time product term did not result in a -2LL decrease of more than 3.84 chi-square points from the previous models, which suggested that linear (straight line) movement of FIM Cognitive trajectories was the best fit for the data.

In the main HLM, FIM Cognitive scores decreased over time. The unstandardized *b*-weights and *p*-values for this HLM appear in Table 3. Lower FIM Cognitive trajectories were seen among participants who had been older at baseline (Figure 9); were underrepresented minorities (Figure 10); had lower educational attainment (Figure 11); were unemployed at the time of injury (Figure 12); had pre-TBI functional limitations in learning (Figure 13) or going out of the home (Figure 14); or had longer length of PTA (Figure 15).

Figure 9

Main Effect of Age at Injury on FIM Cognitive Trajectories

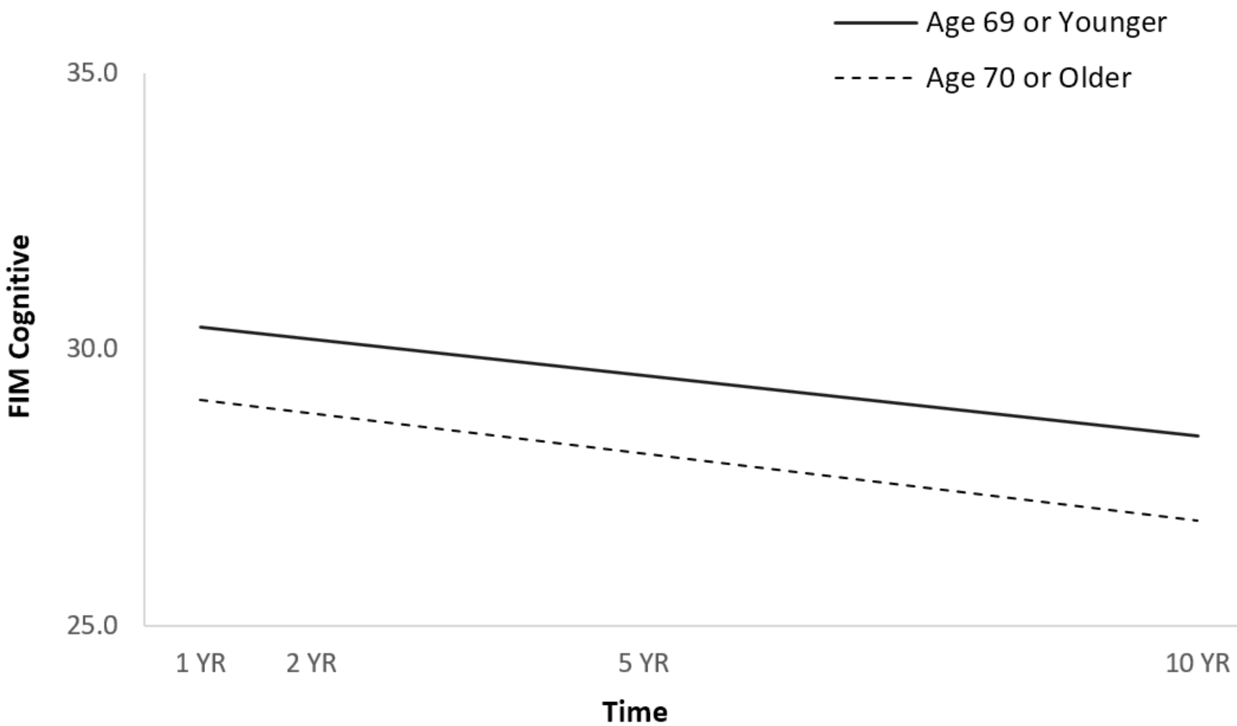


Figure 10

Main Effect of Race/Ethnicity on FIM Cognitive Trajectories

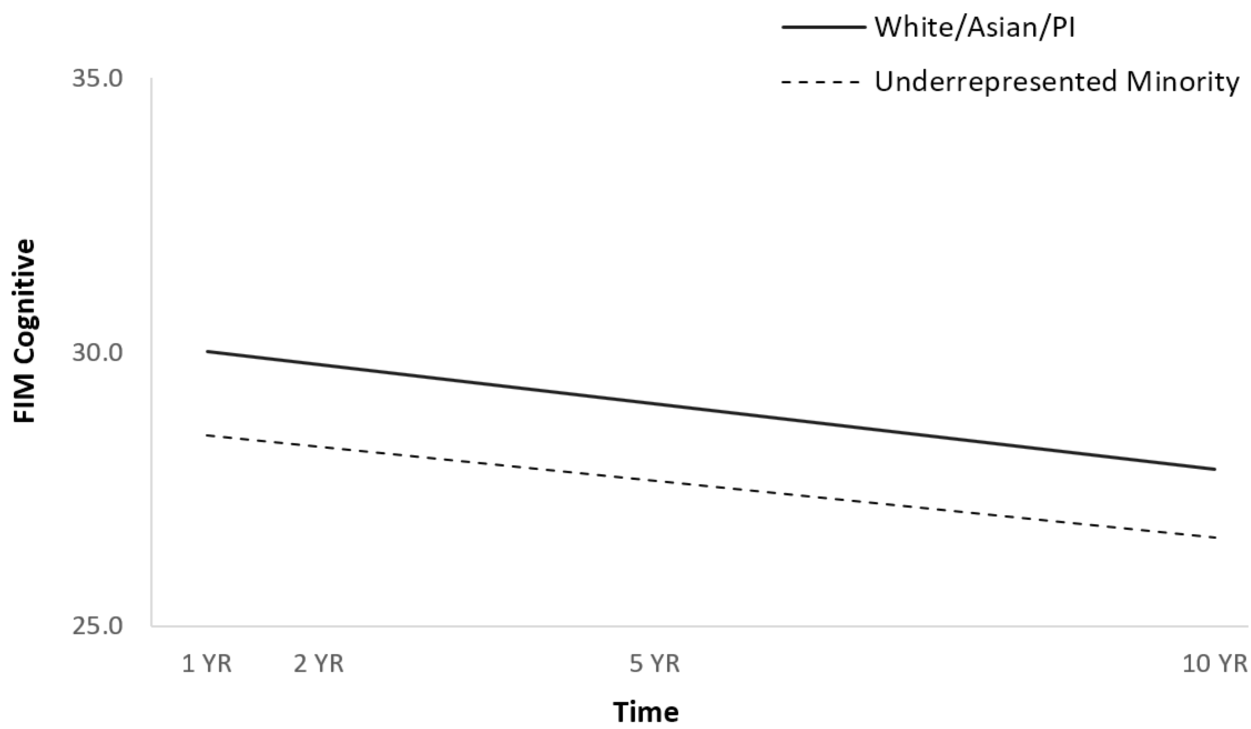


Figure 11

Main Effect of Education on FIM Cognitive Trajectories

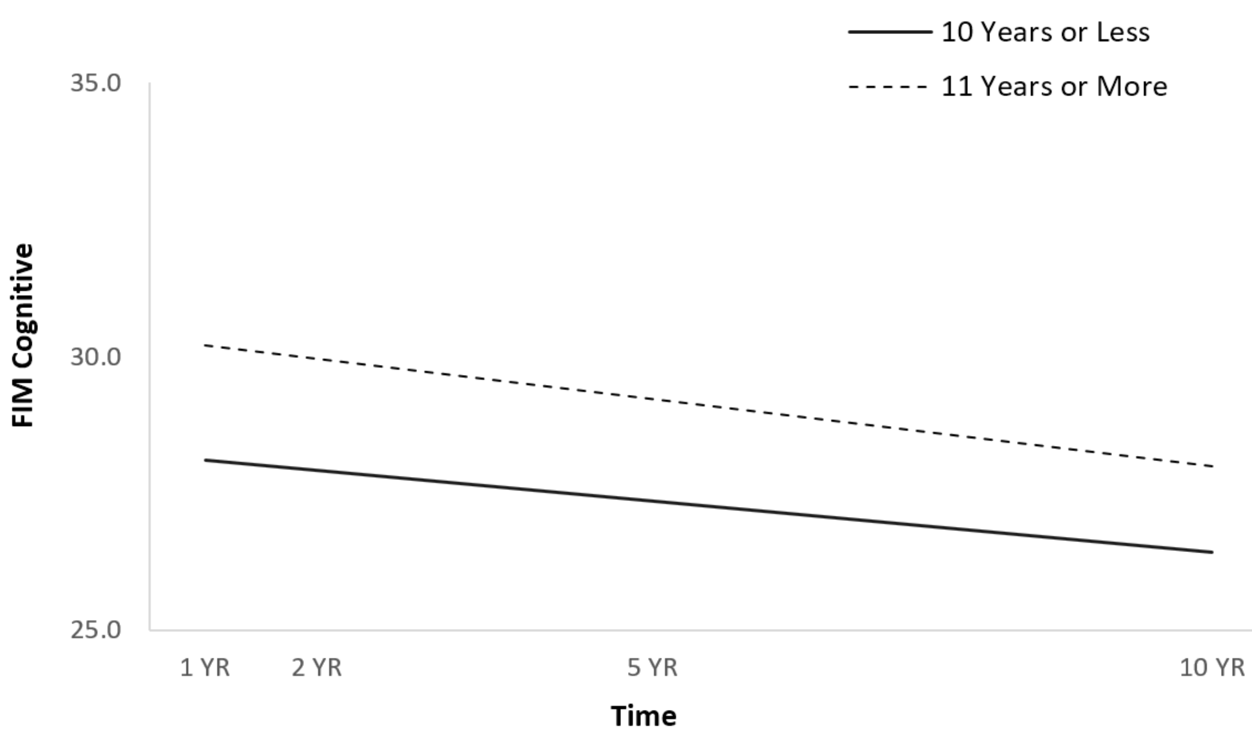


Figure 12

Main Effect of Employment at Injury on FIM Cognitive Trajectories

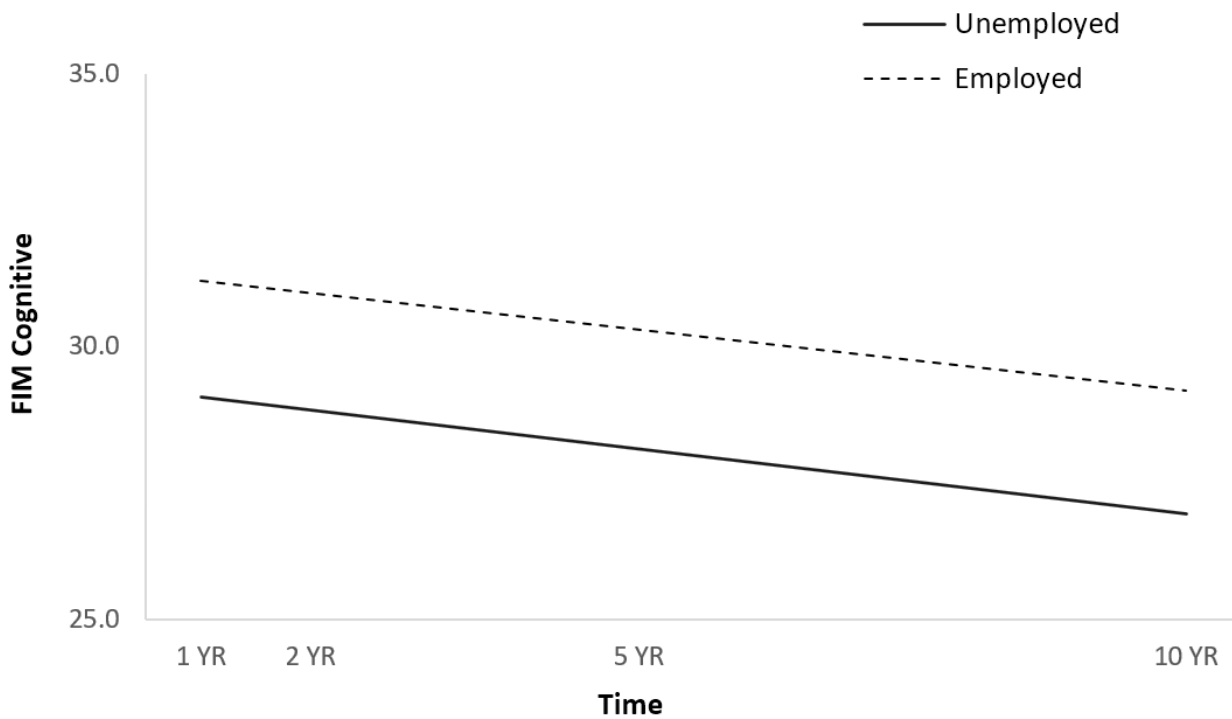


Figure 13

Main Effect of Pre-TBI Limitations in Learning on FIM Cognitive Trajectories

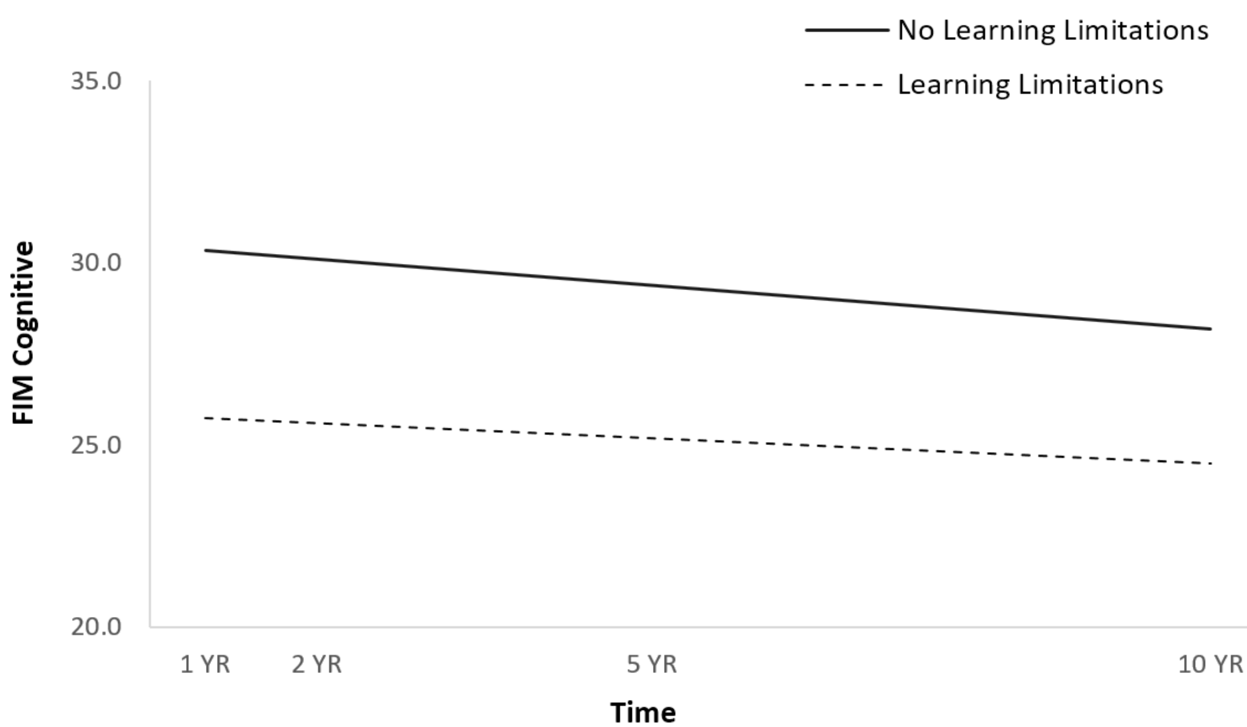


Figure 14

Main Effect of Pre-TBI Limitations in Going out of the Home on FIM Cognitive Trajectories

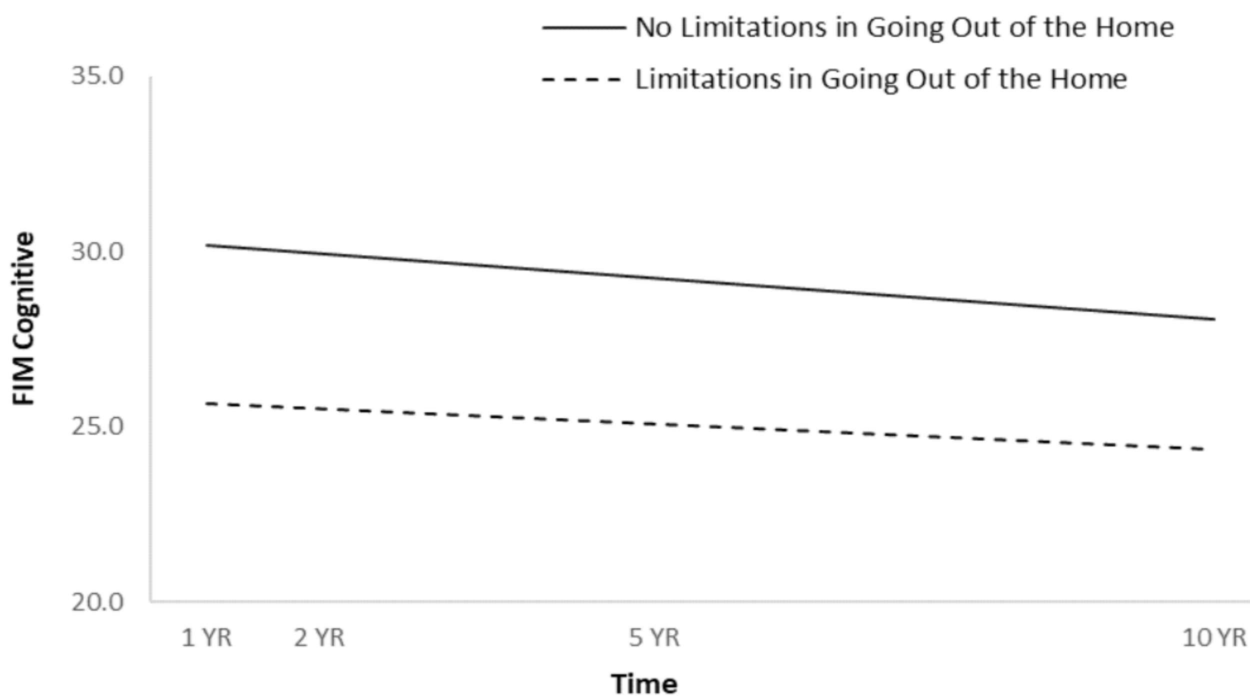
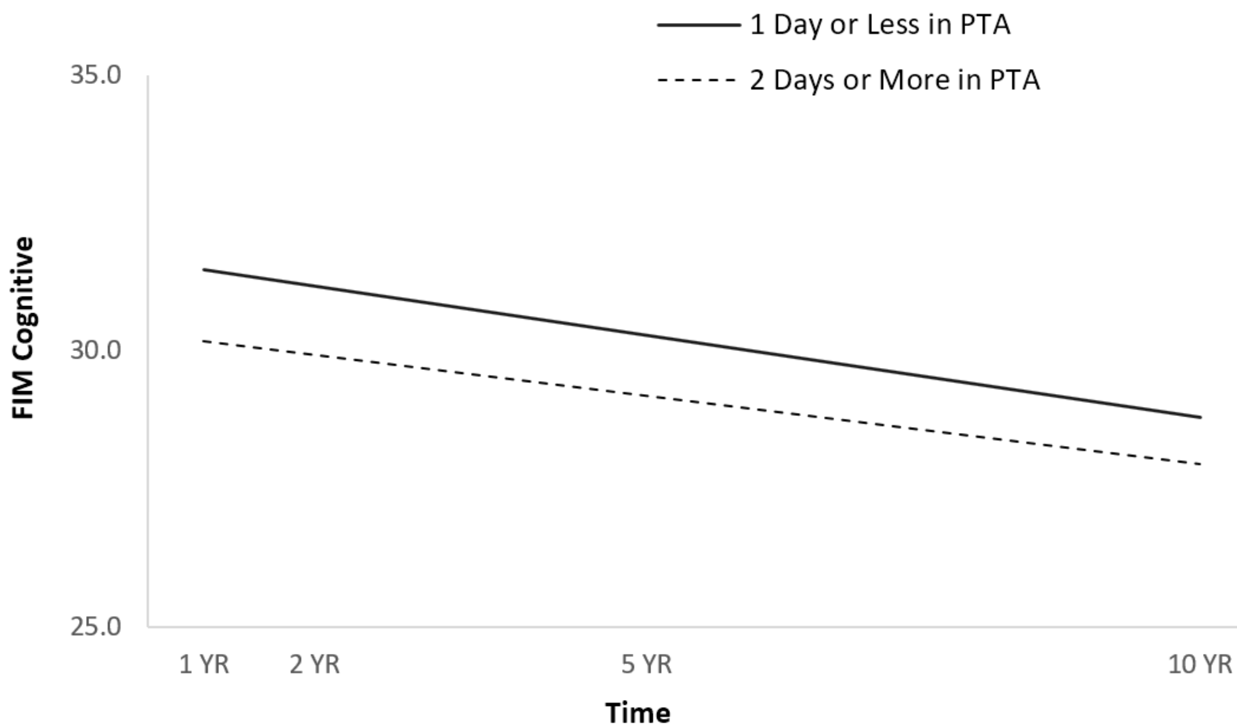


Figure 15

Main Effect of Days in PTA on FIM Cognitive Trajectories



Follow-up HLMs examined whether linear trajectories of FIM Cognitive could be predicted by the previously significant predictors and their interactions with time (Table 4). There were significant interactions for time*age, time*employment status at baseline, time*pre-TBI limitations in going out of the home, and time* PTA, suggesting a differential change over time in functional cognitive independence as a function of these characteristics. The significant time*age interaction suggested that FIM Cognitive scores decreased for all participants but decreased at a faster rate for those who had sustained their TBI at an older age (Figure 9). The significant time*employment interaction suggested that FIM Cognitive scores decreased over time for those who had been employed at the time of injury and for those who had been unemployed at the time of injury but decreased at a faster rate for those who had been unemployed at the time of injury (Figure 12). The significant time*pre-TBI limitations in going out of the home interaction suggested that FIM Cognitive scores decreased over time for all participants but at a slightly faster rate for those who had had no pre-injury limitations in going out of the home (Figure 14). The significant time*injury severity interaction suggested that FIM Cognitive scores decreased over time for all participants but at a slightly faster rate for those who had less severe TBI (Figure 15).

GOS-E

The -2LL of the initial model with linear time was 25,454.53; the -2LL of the model with the addition of quadratic time was 25,446.77; and the -2LL of the model with the addition of cubic time was 25,446.66. The addition of a time product term to the initial model resulted in a decrease of more than 3.84 chi-square points, but the addition of cubic time did not result in a decrease of more than 3.84 chi-square points, which suggested that quadratic movement of GOS-E trajectories was the best fit for the data.

In the main HLM, GOS-E scores decreased over time. The unstandardized *b*-weights and *p*-values for this HLM appear in Table 3. Lower GOS-E trajectories were seen among participants who had been older at baseline (Figure 16); were male (Figure 17); were underrepresented minorities (Figure 18); had lower educational attainment (Figure 19); did not have a history of substance use disorder (Figure 20); had pre-TBI functional limitations in learning (Figure 21), working (Figure 22), or going out of the home (Figure 23); and had longer PTA (Figure 24).

Figure 16

Main Effect of Age on GOS-E Trajectories

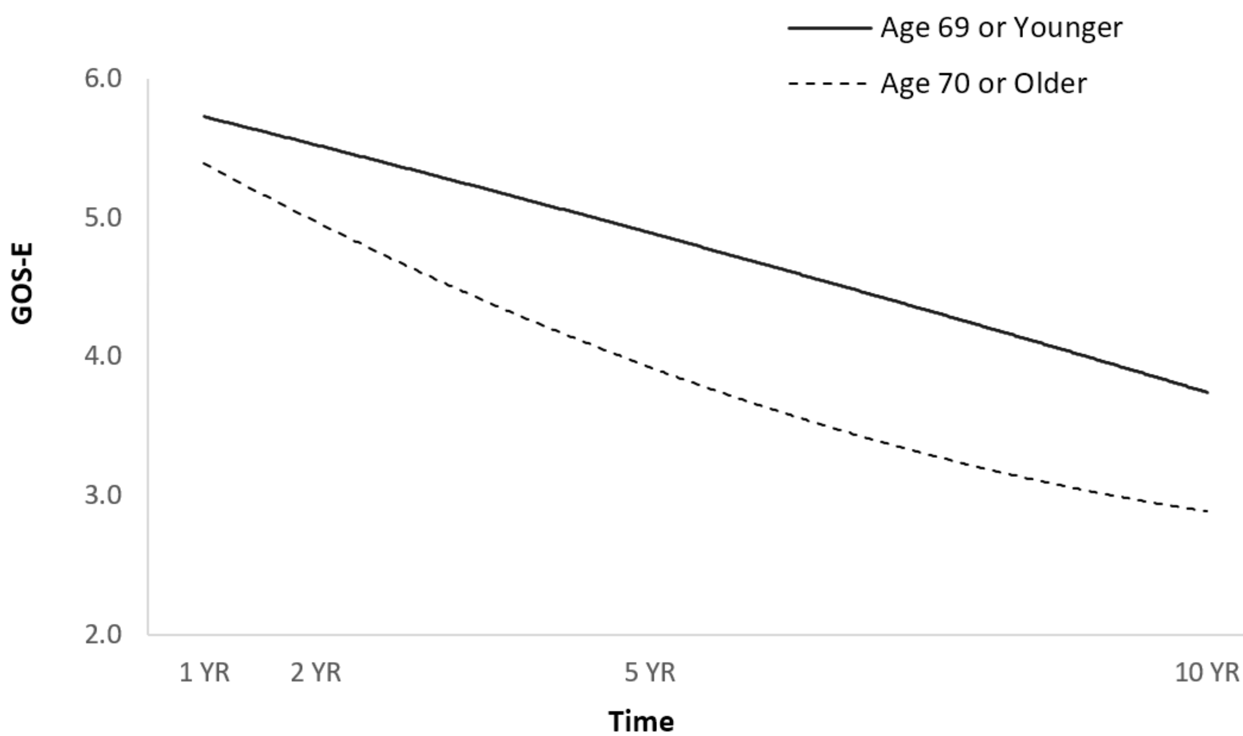


Figure 17

Main Effect of Sex on GOS-E Trajectories

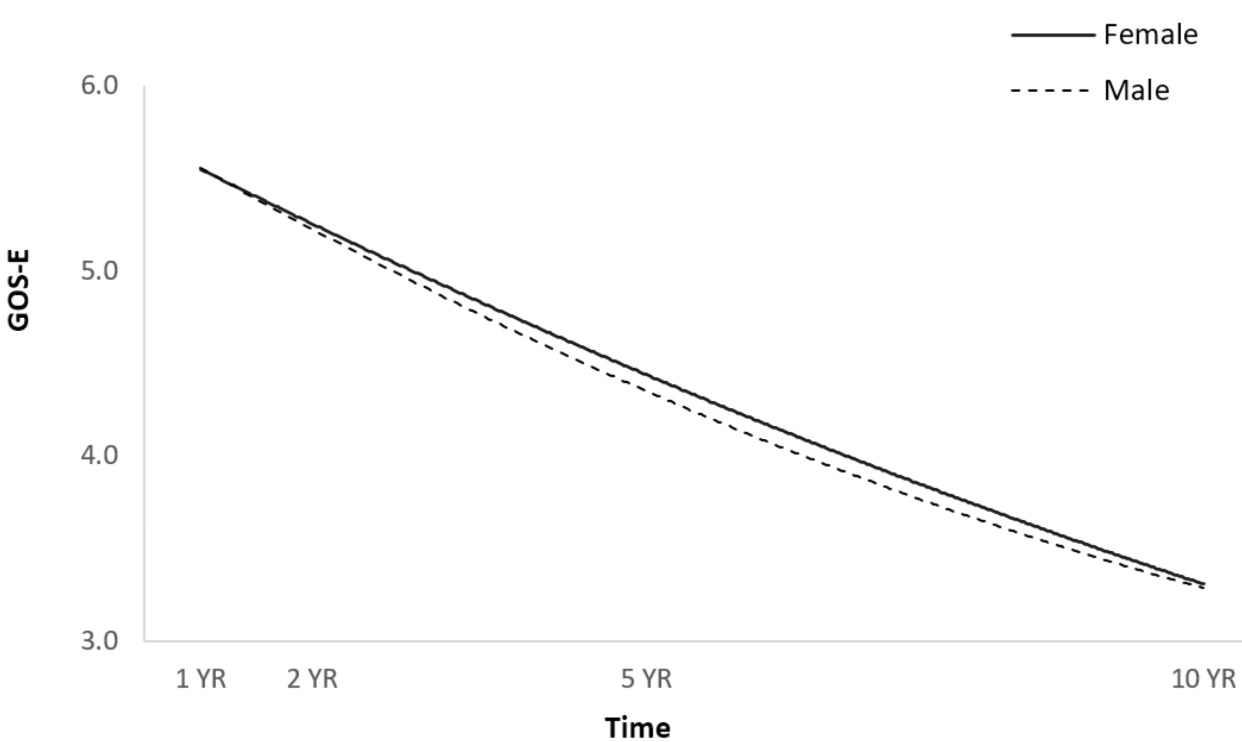


Figure 18

Main Effect of Race/Ethnicity on GOS-E Trajectories

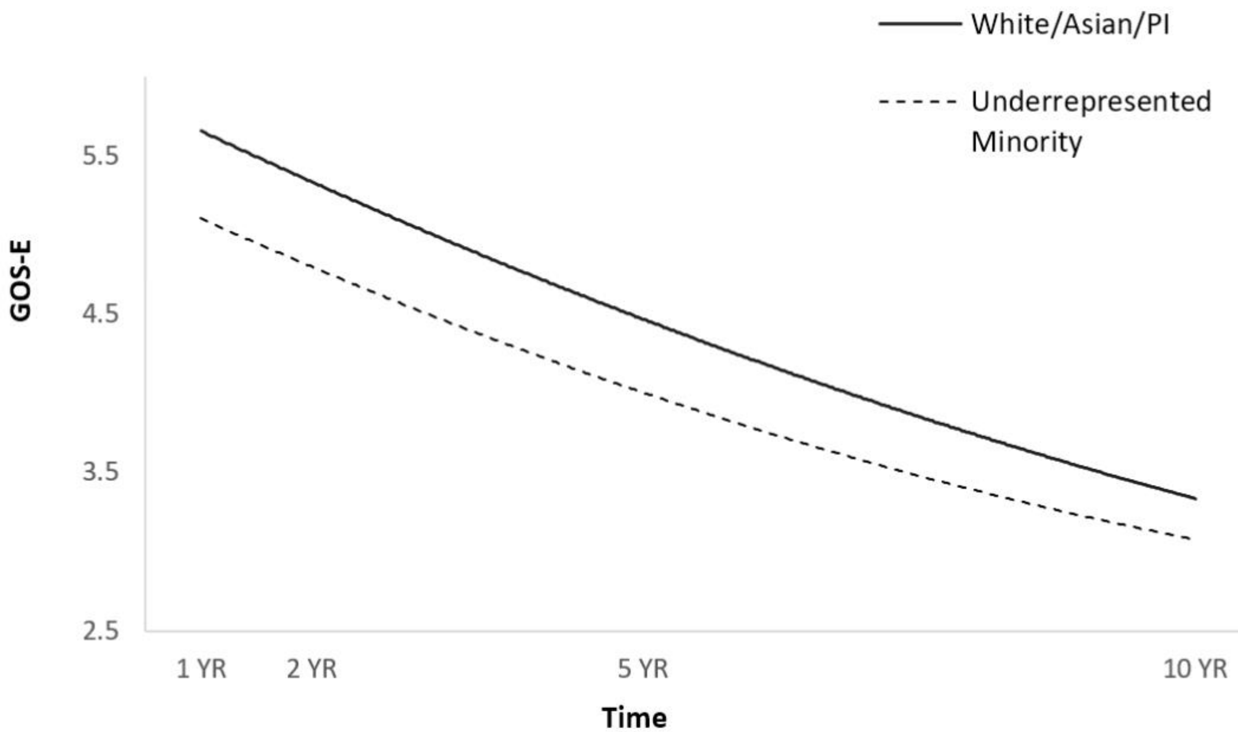


Figure 19

Main Effect of Education on GOS-E Trajectories

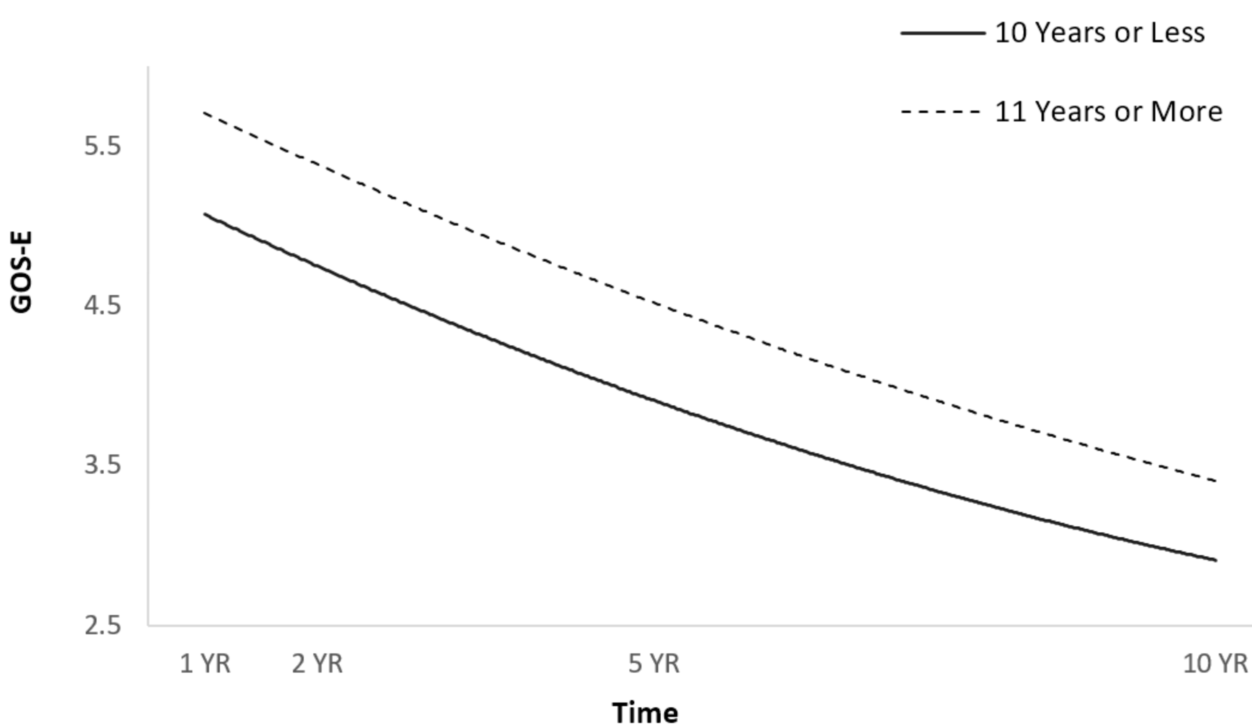


Figure 20

Main Effect of Substance Use History on GOS-E Trajectories

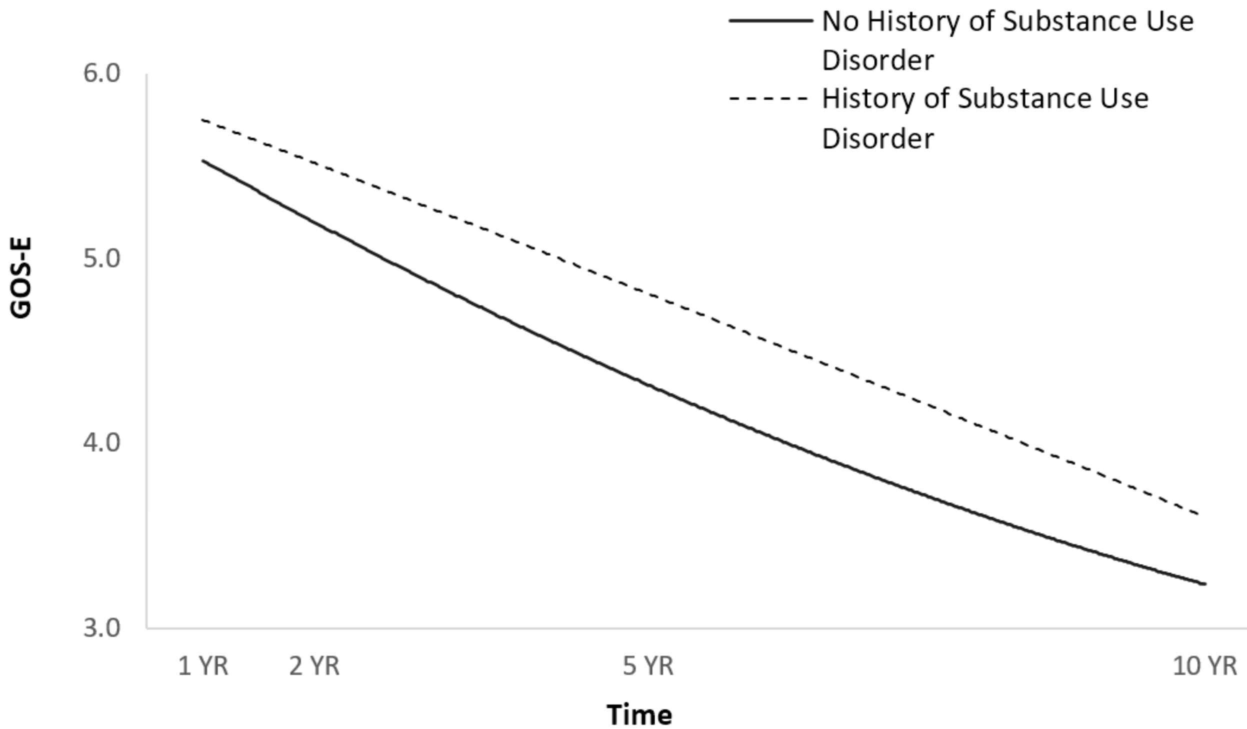


Figure 21

Main Effect of Pre-TBI Limitations in Learning on GOS-E Trajectories

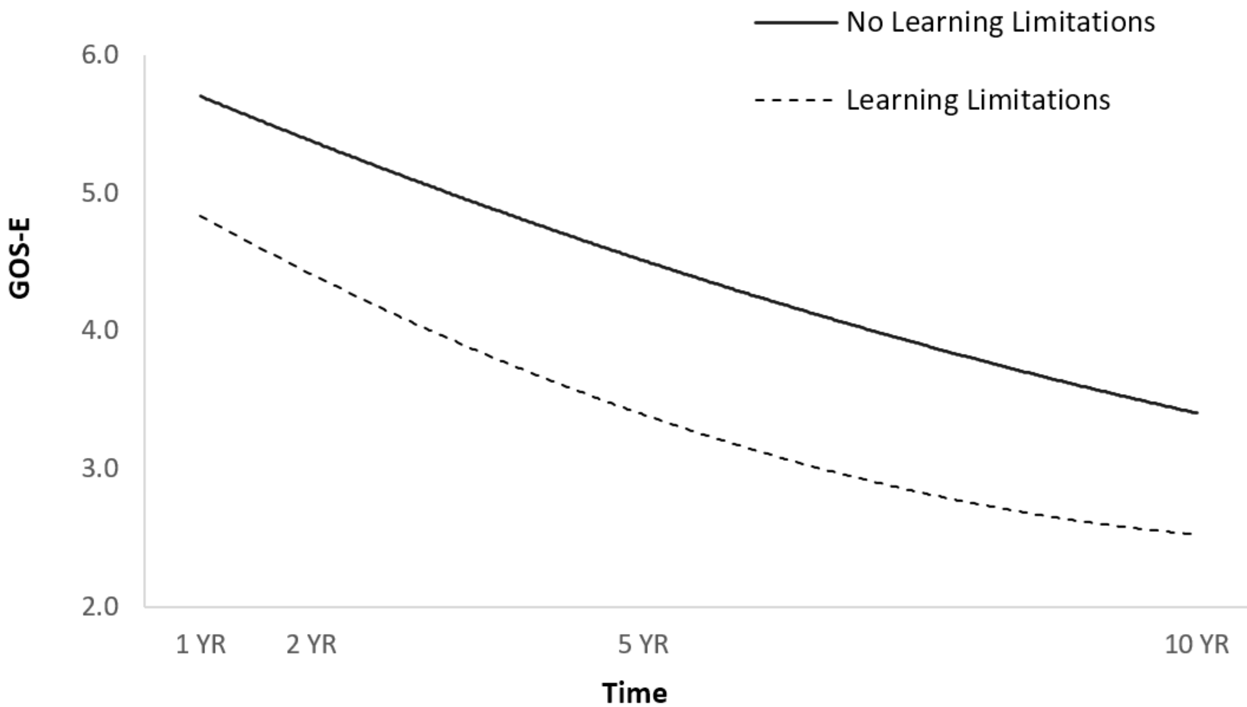


Figure 22

Main Effect of Pre-TBI Limitations in Working on GOS-E Trajectories

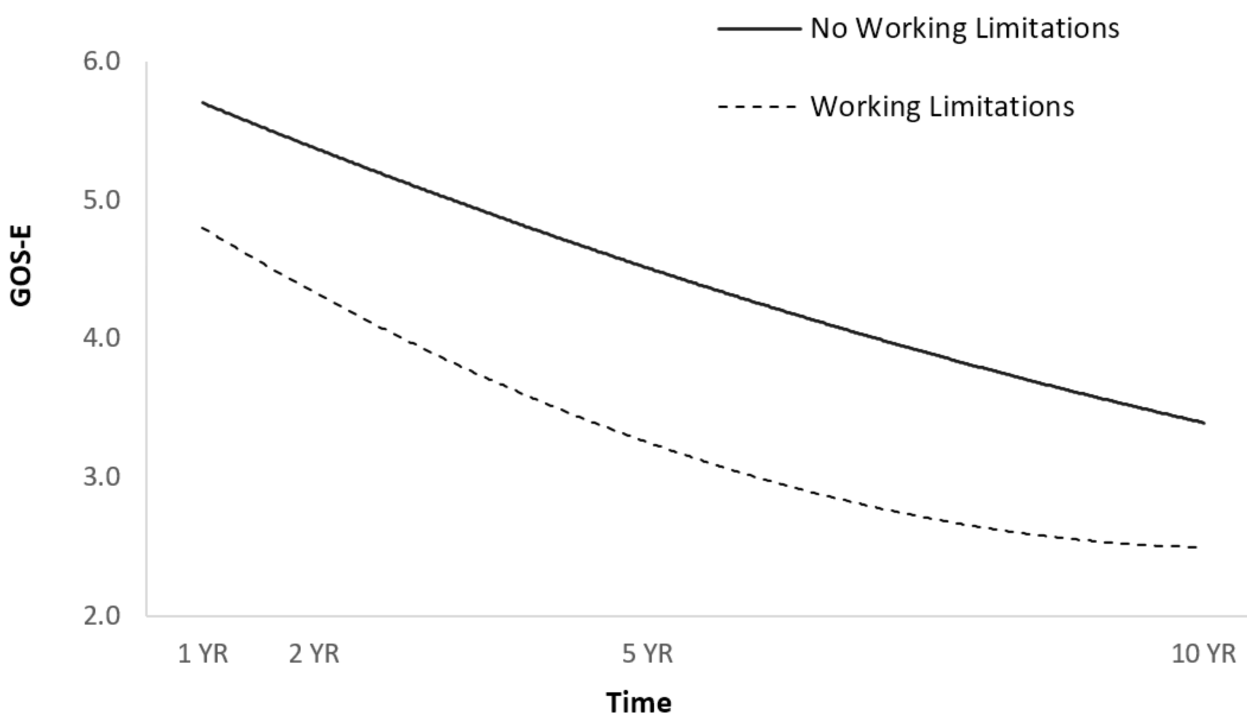


Figure 23

Main Effect of Pre-TBI Limitations in Going Out of the Home on GOS-E Trajectories

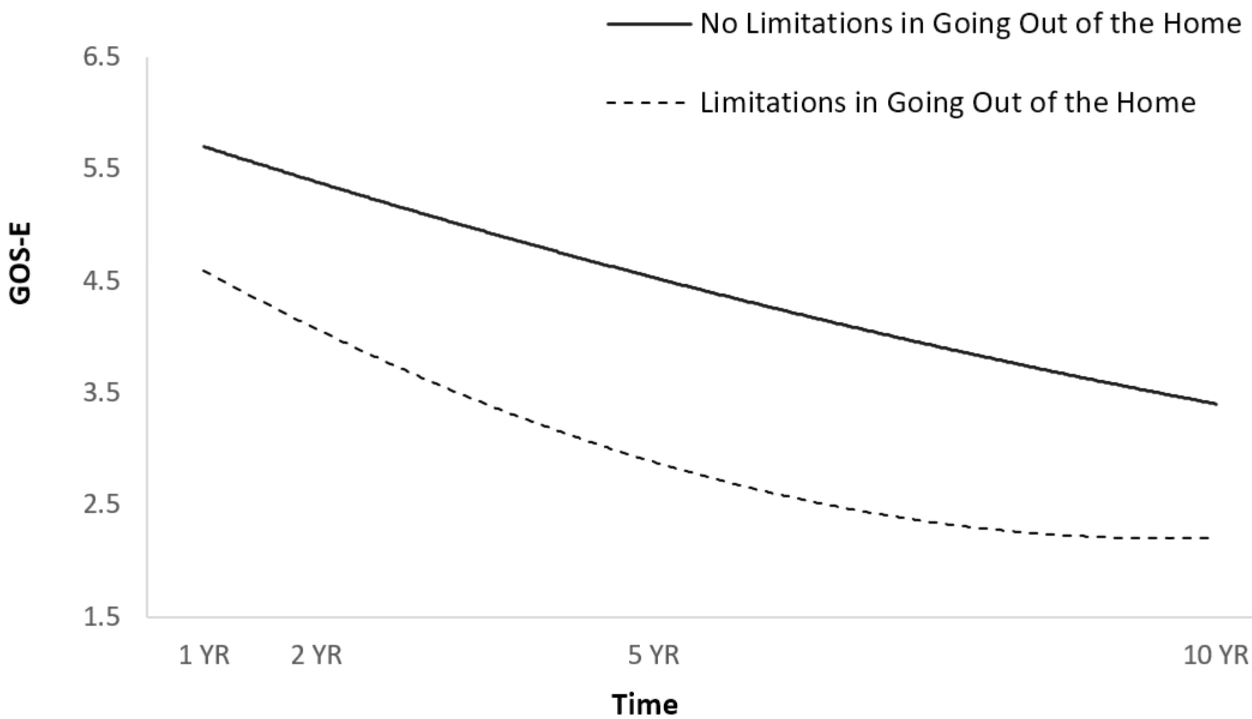
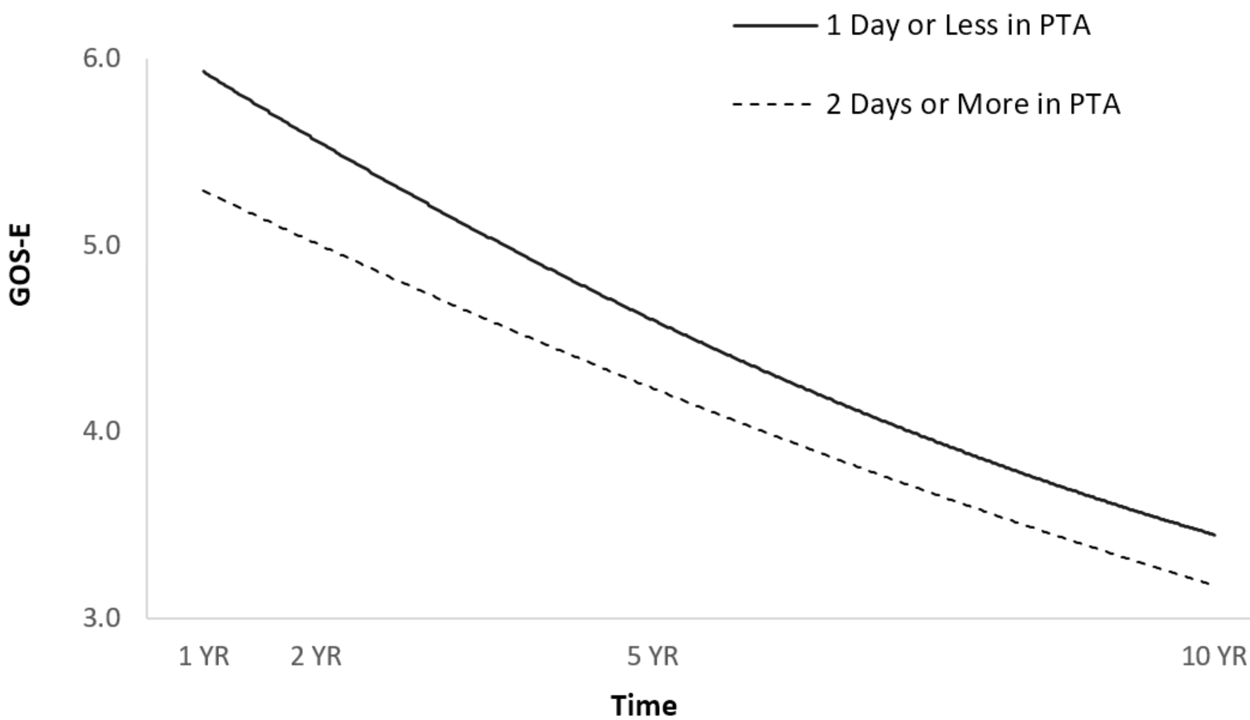


Figure 24

Main Effect of PTA on GOS-E Trajectories



Follow-up HLMs examined whether quadratic trajectories of GOS-E scores could be predicted by the previously significant predictors and their interactions with time*time (Table 4). There were significant interactions for time*time*age, time*time*race/ethnicity, time*time*pre-TBI limitations in working, and time*time*pre-TBI limitations in going out of the home, suggesting a differential change over time in global outcomes as a function of these characteristics. The significant time*time*age interaction suggested that GOS-E scores decreased for younger participants at a steady rate over time but decreased faster for older participants across approximately the first three time points and then slowed the rate of decrease between the third and fourth time point (Figure 16). The significant time*time*race/ethnicity interaction suggested that GOS-E scores decreased over time for all participants but at a faster rate for those who were not underrepresented minorities, with slower decreases for all participants between the third and fourth time points (Figure 18). The significant time*time*pre-TBI limitations in working interaction suggested that GOS-E scores decreased over time for all participants, with the steepest and steadiest decrease in those with no pre-TBI working limitations and a faster rate of decrease in those with pre-TBI working limitations across the first three time points, with the rate of decrease leveling out at the fourth time point (Figure 22). The significant time*time*pre-TBI limitations in going out of the home interaction suggested that GOS-E scores decreased at a steadier rate for those who had had no pre-TBI limitations in going out of the home, while scores for those who had had pre-TBI limitations in going out of the home decreased faster between the first three time points and then slowed until the decrease evened out (no more decrease) as it approached Year 10 (Figure 23).

Discussion

Older adults have greater risk for TBI and lower rehabilitation outcomes after TBI relative to individuals from many other age categories. Understanding contributors to the reduced outcomes in this population is vital for potential interventions to mitigate these risk factors as much as possible. Therefore, the aim of the current study was to examine the roles of sociodemographic and injury severity characteristics as predictors of functional independence trajectories across the first 10 years after TBI in adults who experienced TBI at age 60 or older. The main HLM analyses showed that functional independence (as measured by FIM Motor, FIM Cognitive, and GOS-E) trajectories generally decreased over the 10 years after TBI. Individuals with several sociodemographic risk factors (i.e., older age, male, underrepresented minority membership, lower education, unemployed at time of injury, no history of substance use disorder, and difficulties with learning, dressing, and going out of the home prior to the TBI), and longer time in PTA had lower functional independence trajectories for at least one of the functional independence measures. FIM Motor, FIM Cognitive, and GOS-E trajectories were significantly predicted by interactions between time terms and age, and FIM Cognitive and GOS-

E trajectories were significantly predicted by time terms and employment at baseline. FIM Motor trajectories were also significantly predicted by the interaction of time and pre-TBI learning limitations. FIM Cognitive trajectories were also significantly predicted by interactions between time and pre-TBI limitations in going out of the home and by time and injury severity. Finally, GOS-E trajectories were also significantly predicted by interactions between time and race/ethnicity, time and pre-TBI limitations in working, and time and pre-injury limitations in going out of the home.

Hypothesis 1

The hypothesis that functional independence would initially increase and then plateau was not supported. Instead, functional independence scores decreased steadily over time across the overall sample. Scores on FIM Motor, FIM Cognitive, and GOS-E had steeper declines for those who had sustained their TBI at an older age (Figures 1, 9, and 16), with GOS-E score rate decreases slowing between years 5 and 10 post-TBI.

Previous research in the general population with TBI has found that FIM scores improve from time of injury to 3 months and GOS-E scores show improvement up until 12 months (Sandhaug et al., 2015), but that greater time post injury predicts decreased physical and cognitive functioning (Sendroy-Terrill et al., 2010), more in line with the current findings and perhaps particularly so as the current study’s older adults may have had accentuated functional declines based on advancing age. Studies have shown that more than half of individuals with TBI get worse or stay the same in the first 5 years of recovery, and a little over a quarter of individuals show improvement during that time (CDC, 2021). A study of functional independence in TBI survivors who were younger at injury (mean age 30 years) found that the majority showed no changes between 5 and 15 years post injury (Hammond et al., 2021), and a study by Lu and colleagues (2018) found that most of their younger sample (aged 16-55) had improved FIM Motor and FIM Cognitive trajectories in the 5 years after TBI when measured at 3 months, 1 year, and 5 years, with the most improvement shown between the 3 month and 1 year time points. The limited work with older adults has found that although recovery is significantly slower for older adults than for younger adults with TBI (Frankel et al., 2006), there is general improvement in FIM motor and cognitive scores in the acute rehabilitation period (Hammond et al., 2019). In the current study, it is likely that rehabilitation gains occurred during the first year, but the data were not granular enough to identify the uptick in functioning. Similar to other long-term study results (e.g., Sendroy-Terrill, 2010), age-related declines in functional independence characterized all three outcomes in the current study, either in a linear movement (FIM) or quadratic curvilinear movement (GOS-E).

Hypothesis 2

The hypothesis that older age at time of injury would be associated with lower functional independence over time was supported with a main effect of age on all three outcome trajectories (Figures 1, 9, and 16). Further, although functional independence in both FIM Motor and FIM Cognitive scores declined for all participants, independence declined at a faster pace for those who had sustained their TBI at an older age. Likewise, GOS-E scores also decreased over time for both younger and older groups, but the decline in functional independence was faster for the older group for approximately the first 5 years after TBI with a slower rate of decrease from years 5 to 10. These results are similar to previous research in the general population with TBI which has found that greater age at injury predicts lower functional independence trajectories (Forslund et al., 2017; Howrey et al., 2017) and declines in functional independence (Sendroy-Terrill et al., 2010) and with older adult studies showing increased age associated with lower odds of living independently (Utomo et al., 2009) and less functional improvement with age (Hammond et al., 2019).

There are several possible explanations for the finding of overall lower trajectories of functional independence in older adults as well as declines over time. One possibility is related to increased physical disability associated with aging independent of sequelae brought about by TBI. Disability rates increase as age increases (BLS, 2019), and most older adults have at least one chronic condition (He et al., 2018), so lower function with increased age could be reflective of increasing co-occurring age-related illnesses and disabilities.

Another possible reason for lower and decreasing functional independence with greater age is decreased social participation. Social involvement after TBI may be constrained because of primary effects such as impaired motivation or ability to be with other people or changes in behavioral regulation and cognition (Tate et al., 1989; Tate & Broe, 1999). In the course of development, older adults already tend to condense the size of their social networks as they age (English & Carstensen, 2014), and while this may be adaptive for promoting emotional wellbeing prior to TBI, it is possible that the additional narrowing of the social network brought about by TBI may severely restrict availability of resources after TBI. Continued engagement in social roles is vital for physical recovery, mental health, and overall quality of life (Bay et al., 2002; Juengst et al., 2015; McClean et al., 2016), and reductions in social participation may adversely affect functional independence in older adults after TBI.

Life expectancies have increased dramatically in the last two centuries, with average worldwide life expectancy in 1800 less than 40 years, and average life expectancy in the U.S. in 2019 being 79 years (Roser et al., 2019). But even with the number and proportion of older adults steadily rising for years (Statista, 2020a), attitudes toward older adults have been slow to change. Stereotypical portrayals of older adults as being inept, unappealing, feeble, and burdens on social systems abound, including in healthcare settings (Wyman et al., 2018). While evidence of ageism in general settings is upsetting, in health care settings ageist beliefs can have serious implications for health outcomes (Chang et al., 2020), such as discrimination in the form of trivialization of symptoms, infantilizing and condescending communications (Vale et al., 2020), and even underordering diagnostic evaluations and treatments (Madan et al., 2006). For example, though greater functional independence outcomes have been achieved when individuals with TBI are discharged from the hospital to a specialized rehabilitation facility, older adults are admitted directly to these facilities less frequently than younger adults, even when injury severity is equivocal (Cuthbert et al., 2011; Sveen et al., 2016). Additionally, when older adults perceive that they have been the subjects of age discrimination and have internalized ageist beliefs, functional impairment and mortality rates are higher (Moser et al., 2011; Ng et al., 2016; Sutin et al., 2015).

Hypothesis 3

The hypothesis that individuals with sociodemographic risk factors would have lower functional independence trajectories after TBI was partially supported. The current study examined the effects of sex, race/ethnicity, partnered status at injury, insurance type at injury, education, employment status at injury, and pre-existing functional limitations on functional independence over the 10 years after injury with FIM Motor, FIM Cognitive, and GOS-E measures. Individuals who were members of an underrepresented racial/ethnic minority group (Figures 2, 10, and 18), had lower educational attainment (Figures 3, 11, and 19), had pre-TBI limitations in learning (Figures 5, 13, and 21), and had pre-TBI limitations in going out of the home (Figures 7, 14, and 23) showed lower functional independence trajectories across all three outcome measures. Additionally, individuals who had pre-TBI functional limitations in dressing showed lower FIM Motor trajectories (Figure 6); individuals who were unemployed at the time of injury showed lower FIM Cognitive trajectories (Figure 12); and males (Figure 17), individuals who did not have a history of substance use disorder (Figure 20), and individuals who had had pre-TBI limitations in working (Figure 22) showed lower GOS-E trajectories. No significant effects on functional independence trajectories were found for partnered status or insurance type.

The hypothesized functional independence trajectory for women being lower than men was not supported. However, FIM Motor and FIM Cognitive functional independence trajectories for sex were not significantly different, and the GOS-E trajectories, though significantly lower for men, were very close (Figure 17). The literature regarding sex as a factor in functional independence after TBI is not definitive, as men have higher TBI-related death rates (Daugherty, 2019), but better global outcome trajectories over time (Forslund et al., 2019). Women have shown have reduced 6- and 12-month outcomes (including lower GOS-E scores) than men after mild TBI (Levin et al., 2021), and women over age 65 have been found to have worse outcomes than same-age men (Mikoli et al., 2021). It is likely that our findings actually support the growing view that more research needs to be done on sex-specific differences in TBI functional outcomes (Gupte et al., 2019).

In the current study, FIM Motor and FIM Cognitive trajectories for those who had a history of substance use and those who did not have such a history were not significantly different. However, we found that GOS-E trajectories for those who did not have a history of substance use were lower than for those who did (Figure 20). This was unexpected, and it is contrary to previous literature which has found generally worse outcomes for those with a history of pre-injury substance misuse prior to their TBI (Corrigan, 1995; Weil et al., 2018; Willemse-van Son et al., 2007). It may be possible that individuals who had received treatment for their substance use disorder may have learned life skills and developed resilience which enabled them to cope better with health challenges, though future research should investigate this interpretation.

Members of underrepresented minority groups had lower functional independence trajectories across all three measures (Figures 2, 10, and 18). This is consistent with literature which documents that underrepresented racial/ethnic minorities have worse functional outcomes over time than do Whites (Arango-Lasprilla et al., 2007a; Arango-Lasprilla et al., 2007b). This may be a result of not having equal access to care, whether through barriers such as language difficulties, uninsured or underinsured status (Shafi et al., 2007), mistrust of the medical community (Boulware et al., 2003; Casagrande et al., 2007), or receiving less inpatient therapy and fewer referrals to rehabilitation services (Arango-Lasprilla & Kreutzer, 2010; Asemota et al., 2013; Burnett et al., 2003; Cuthbert et al., 2011; Mellick et al., 2003). Racial/ethnic minorities with TBI are less likely to be married (Vanderploeg et al., 2003), and marriage can be a protective factor against adverse physiological conditions (Wong & Waite, 2015). Minorities also have less steady competitive employment after TBI than racial/ethnic majority members (Arango-Lasprilla et al., 2010; Gary et al., 2009). While underrepresented racial/ethnic minorities did have lower functional independence trajectories, only GOS-E scores showed a significant interaction with time, with functional independence decreasing over time at a faster rate for those who were not underrepresented minorities. The rate of decline slowed for all participants between 5 and 10 years (Figure 18). This interaction with time may well be a demonstration of the regression toward the mean phenomenon.

Educational attainment levels showed main effects on functional independence across all three outcome measures, with individuals of lower educational attainment having lower functional independence trajectories. This is consistent with literature which has found that higher education levels are associated with better physical and cognitive functioning (e.g., Azouvi et al., 2016; Schonberger et al., 2011; Shumway-Cook et al., 2009). It is still somewhat unclear why higher education should be associated with better functional outcomes, especially with some studies finding that education level itself does not predict global outcome trajectories (Forslund et al., 2019) after TBI. Proposed theories for the education–improved outcomes association include development of better cognitive reserve and compensatory ability (Giovacchini et al., 2019; Levi et al., 2013; Ponsford et al., 2008; Wilson et al., 2019), as well as healthier lifestyles and access to healthcare (Fletcher & Frisvold, 2009; Mather & Scommegna, 2020; Wang et al., 2013).

Individuals who had been unemployed at injury had lower FIM Motor and FIM Cognitive trajectories (Figures 4 and 12). This finding is consistent with other studies which have found that employment at injury predicts employment after TBI (Gary et al., 2009) and lower disability (Willemse-van Son et al., 2007). Further, FIM Cognitive scores decreased at a slightly faster pace for those who had been unemployed at the time of injury (Figure 12). The FIM Cognitive finding is consistent with previous literature which found that being employed at time of injury predicts higher functional trajectories over time (Forslund et al., 2017) and that cognitive function is higher for older adults who stay in the workforce compared to those who remain retired (Lee et al., 2019).

Individuals with pre-TBI health limitations in learning (Figures 5, 13, and 21) and going out of the home (Figures 7, 14, and 23) had lower functional independence trajectories across all three outcome measures. Those with pre-injury limitations in dressing had lower FIM motor trajectories (Figure 6), and those with limitations in working had lower GOS-E trajectories (Figure 22). Pre-TBI limitations to performance of ADLs such as dressing may be indicative of overall poorer pre-TBI functioning, and it is therefore not unexpected to see this trend continue after TBI. Pre-TBI learning limitations showed a significant effect over time only for FIM Motor scores, as those who had had no pre-injury learning limitations showed a slightly faster rate of decline over 10 years than those who had pre-injury learning limitations (Figure 5). The slightly steeper rate of decline may be more representative of the decline in motor functioning which would typically be associated with aging, as individuals who had had pre-TBI learning limitations showed 1 year follow-up scores which were lower than the 10-year scores of those who had had no pre-injury limitations in learning. FIM Cognitive scores for those with pre-TBI limitations in going out of the home decreased at a slightly slower rate than for those with no such limitations (Figure 14), but GOS-E scores for those with limitations in going out of the home prior to their TBI decreased faster across the first three time points, with the rate of decrease slowing between years 5 and 10 until the decrease leveled out as it approached year 10 (Figure 23). It may be that as GOS-E includes both motor and cognitive indices, the FIM Cognitive scale was picking up the most prevalent area of decline, possibly more noticeable for those with fewer limitations on going out of the home at injury. GOS-E trajectories decreased more quickly across the first 5 years for those with pre-TBI working limitations, with the rate of decrease leveling out at 10 years post-TBI (Figure 22). Similar to findings related to employment at injury, these findings may be reflective of higher functional trajectories over time (Forslund et al., 2017) for those who had been employed at injury.

Hypothesis 4

The hypothesis that individuals with more severe TBI would have lower functional independence over time was supported. Individuals who had greater injury severity had lower functional independence across all three outcome trajectories (Figures 8, 15, and 24). This is consistent with studies showing longer time in PTA predicts reduced global outcomes over time (Forslund et al., 2017; Forslund et al., 2019). Additionally, FIM Cognitive scores decreased over time at a slightly faster rate for those with less severe TBI (Figure 15). This may be associated with more noticeable age-related declines over time when TBI-related debilities are not subsuming age-related declines.

Clinical Implications for Older Adults with TBI

The growing number and proportion of older adults makes it likely that clinicians will see more cases of TBI in this population, especially for those aged 80 years and older (CDC, 2019b; Vespa et al., 2020). As morbidity and mortality rates are highest for older adults compared to other age groups (Dams-O'Connor, 2013; Gardner et al., 2018), awareness of risk factors for reduced post-TBI outcomes in this group is the first critical step for treatment planning. In older adults with TBI, it is important for health care professionals to note increased risk for comparatively poorer outcomes associated with increased age, underrepresented minority status, lower educational attainment, being unemployed at injury, pre-TBI health comorbidities, and greater number of days in PTA. Knowing that older adults face higher morbidity and mortality after TBI, identification of the above risk factors should be a priority at intake, with subsequent implementation of treatment regimens specific to older adults. For example, physical and psychological interventions should take into consideration pre-TBI limitations (e.g., health comorbidities, decreased social networks, effects of ageism) and the possibility that formal rehabilitation programs may need to be intensified, broader in scope, and longer in duration than is typical when basing treatment plans on standards established for younger people with TBI.

As some sociodemographic risk factors do not lend themselves to being addressed post-TBI (e.g., age, employment status at time of injury, and educational attainment), more efforts should be geared toward educating older adults about the increased risks associated with incurring TBI in older adulthood. Concerted educational endeavors on ways to offset these risk factors such as maintaining social engagement, reducing fall risks, adopting lifestyle habits that support better physical and mental health, and engaging in meaningful work may help older adults to exert control over mitigation of some of the risk factors associated with reduced outcomes after TBI.

Examination of factors predicting trajectories of functional independence in older adults provides important information not only for areas of intervention but also for timing of potential interventions to mitigate dysfunction and to promote greater recovery, which in turn can reduce cost burdens on healthcare systems, health insurance systems, local and national economies, and family and social systems.

Limitations and Future Directions

The current study has several limitations which should be considered when interpreting its findings, and as a result, directions for future research. When conducting a longitudinal study over 10 years and limiting the sample to adults aged 60 and older with complex medical histories, it is understandable that there would be a number of participants who would be lost to follow up due to illness or death. Participants who are underrepresented minorities, have lower socioeconomic status, a history of substance use, or injury caused by violence are those who are most often lost to follow-up in the 2 years post TBI (Corrigan et al., 2003). In order to retain sufficient data for analysis at the 5- and 10-year time points and not only include participants with complete data (and therefore healthier participants), advanced statistical methods (FIML and expectation maximization) were used to account for or estimate missing values. As attrition was fairly high at follow-up years 5 and 10, it is likely that analyses included data which was estimated for individuals who were deceased at one or more time points, especially since missingness reached approximately 87% for FIM scores at year 10. Therefore, point estimates further out should be interpreted with caution. As additional data are compiled over the next few years, this study should be replicated to validate these results with data having lower missingness rates for the later time points.

Although the TBIMS database contains a wide array of variables, there were limitations to the information available at the time of this study. For example, Form I (baseline) of the TBIMS database had no comprehensive index of either cognition or mental health, and participating TBIMS sites only recently started adding data regarding many of the pre-existing health conditions common in older adults, such as congestive heart failure, diabetes, and disordered sleep. As these may be important considerations when examining functional outcomes after TBI in older adults, pre-injury functional limitations to learning, dressing, going out of the home, and working, and substance use history and treatment for mental health conditions were used as proxies for pre-injury physical and mental health status. When sufficient data on comorbidities common in older adults, formal indices of mental health and cognition, and health contributors such as sleep patterns at the time of injury become more available, functional outcomes in older adults with TBI should be reexamined to confirm our findings with consideration of those variables.

As the current study's sample was limited to participants who were part of the TBIMS database, it is possible that these results are not generalizable to the general population of older adults with TBI. Studies have found that the proportion of older adults admitted to rehabilitation nationally is higher than the proportion of older adults included in the TBIMS system, injury severity is greater for those in TBIMS hospitals, and insurance types differ for those in the TBIMS system versus not (Corrigan et al., 2007; 2012; Cuthbert et al., 2012). Possible contributors to these differences could include limitations related to availability and accessibility, whether due to geographic, socioeconomic, or discriminatory factors. It will be important for future studies to consider these differences when generalizing findings to the general population.

Although the hypothesis regarding the trajectory of improvement in functional independence after TBI was not supported, using multi-year epochs for the follow-up time points may have been too wide a span to detect patterns of improvement between time of discharge and year 1, the time between year 1 and year 2, etc. Future studies should examine recovery trajectories in smaller time intervals in order to discover any potential differences in functional independence outcomes in older adults after TBI than those found in the current study.

Similarly, as scores for the outcome measures (FIM Motor, FIM Cognitive, and GOS-E) were total scores, it is difficult to distinguish which items were responsible for decreased functional independence trajectories. For example, within the FIM Motor total score, participants may have been able to accomplish one or more of the tasks (e.g., eating, dressing, etc.) independently while requiring assistance in other items (e.g., toileting, locomotion, etc.). Using aggregate scores makes it impossible to differentiate exactly which constructs constitute deficits and strengths. Additionally, as some of the variables represented within the total scores may be unlikely to change, results may be biased when looking at change over time.

As development of several serious illnesses such as Parkinson's disease, Alzheimer's disease, schizophrenia, and depression (Gardner et al., 2015; Ikonomovic et al., 2017; Jean-Bay, 2000; & Molloy et al., 2011) have been linked to TBI, tracking the relationship between these conditions and functional independence outcomes over time could be particularly informative in differentiating rehabilitation trajectories and treatment planning. Likewise, it is possible that participants in this study may have already been experiencing these and other chronic conditions so that decreased trajectories may have in fact been due to the effects of these conditions and not the TBI.

Conclusion

Many studies have shown that older adults with TBI have reduced rehabilitation outcomes compared to younger people, and the current study showed that this trend holds true throughout the older adult lifespan, with increasing age being a significant factor in predicting reduced long-term outcome trajectories. Moreover, in addition to increased age, this study identified several other risk factors for reduced functional independence in older adults with TBI, specifically: male; Black, Hispanic, Native American, or Other (not White, Asian, or Pacific Islander); lower educational attainment; unemployed at time of injury; no history of substance use; difficulties with learning, dressing, and going out of the home prior to the TBI; and longer time in PTA. Additionally, FIM Motor, FIM Cognitive, and GOS-E trajectories were significantly predicted by interactions between time terms and a number of other demographic and injury-severity variables. The significant predictors of long-term functional independence trajectories in older adults with TBI identified in this study may serve individuals with TBI and care providers by heightening awareness of the need for attention to these factors in treatment planning and long-term health monitoring and ultimately as a way to decrease morbidity and mortality in this older adult population.

References

American Psychiatric Association. (2013). Neurocognitive disorders. In *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Arango-Lasprilla, J. C., Ketchum, J. M., Dezfulian, T., Kreutzer, J. S., O’neil-Pirozzi, T. M., Hammond, F., & Jha, A. (2008). Predictors of marital stability 2 years following traumatic brain injury. *Brain Injury*, *22*(7–8), 565–574. https://doi.org/10.1080/02699050802172004

Arango-Lasprilla, J. C., Ketchum, J. M., Gary, K. W., Kreutzer, J. S., O’Neil-Pirozzi, T. M., Wehman, P., Marquez de la Plata, C., & Jha, A. (2009). The influence of minority status on job stability after traumatic brain injury. *Physical Medicine and Rehabilitation, 1*, 41-49. https://doi:10.1016/j.pmrj.2008.07.001

Arango-Lasprilla, J. C., & Kreutzer, J. S. (2010). Racial and ethnic disparities in functional, psychosocial, and neurobehavioral outcomes after brain injury. *Journal of Head Trauma Rehabilitation*, *25*(2), 128-136. https://doi.org/10.1097/HTR.0B013E3181D36CA3

Arango-Lasprilla, J. C., Rosenthal, M., Deluca, J., Komaroff, E., Sherer, M., Cifu, D., & Hanks, R. (2007a). Traumatic brain injury and functional outcomes: Does minority status matter? *Brain Injury*, *21*(7), 701–708. https://doi.org/10.1080/02699050701481597

Arango-Lasprilla, J. C., Rosenthal, M., DeLuca, J., Cifu, D. X., Hanks, R., & Komaroff, E. (2007b). Functional outcomes from inpatient rehabilitation after traumatic brain injury: How do Hispanics fare? *Archives of Physical Medicine and Rehabilitation*, *88*(1), 11–18.

Asemota, A. O., George, B. P., Cumpsty-Fowler, C. J., Haider, A. H., & Schneider, E. B. (2013). Race and insurance disparities in discharge to rehabilitation for patients with traumatic brain injury. *Journal of Neurotrauma*, *30*(24), 2057–2065. https://doi.org/10.1089/neu.2013.3091

Ashley, J. G., Ashley, M. J., Masel, B. E., Randle, K., Kreber, L. A., Singh, C., Harrington, D., & Griesbach, G. S. (2018). The influence of post-acute rehabilitation length of stay on traumatic brain injury outcome: A retrospective exploratory study. *Brain Injury*, *32*(5), 600–607. https://doi.org/10.1080/02699052.2018.1432896

Azouvi, P., Ghout, I., Bayen, E., Darnoux, E., Azerad, S., Ruet, A., Vallat-Azouvi, C., Pradat-Diehl, P., Aegerter, P., Charanton, J., & Jourdan, C. (2016). Disability and health-related quality-of-life 4 years after a severe traumatic brain injury: A structural equation modelling analysis. *Brain Injury*, *30*(13–14), 1665–1671. https://doi.org/10.1080/02699052.2016.1201593

Barker-Collo, S., Jones, K., Theadom, A., Starkey, N., Dowell, A., McPherson, K., Ameratunga, S., Dudley, M., Te Ao, & Feigin, V. (2015). Neuropsychological outcome and its correlates in the first year after adult mild traumatic brain injury: A population-based New Zealand study. *Brain Injury*, *29*(13-14), 1604–1616. https://doi.org/10.3109/02699052.2015.1075143

Bay, E., Hagerty, B. M., Williams, R. A., Kirsch, N., & Gillespie, B. (2002). Chronic stress, sense of belonging, and depression among survivors of traumatic brain injury. *Journal of Nursing Scholarship*, *34*(3), 221–226. http://doi.org/10.1111/j.1547-5069.2002.00221.x

Bhattacharya, B., Maung, A., Schuster, K., & Davis, K. A. (2016). The older they are the harder they fall: Injury patterns and outcomes by age after ground level falls. *Injury*, *47*(9), 1955–1959. https://doi.org/10.1016/j.injury.2016.06.019

Bogner, J. A. , Whiteneck, G. G. , MacDonald, J. , Juengst, S. B. , Brown, A. W. , Philippus, A. M. , Marwitz, J. H. , Lengenfelder, J. , Mellick, D. , Arenth, P. & Corrigan, J. D. (2017). Test-Retest reliability of traumatic brain injury outcome measures: A Traumatic

Brain Injury Model Systems study. *Journal of Head Trauma Rehabilitation, 32* (5), E1-E16. doi: 10.1097/HTR.0000000000000291.

Boulware, L. E., Cooper, L. A., Ratner, L. E., LaVeist, T. A., & Powe, N. R. (2003). Race and trust in the health care system. *Public Health Reports*, *118*(4), 358–365.

Brain Injury Association (BIA). (2011). *About Brain Injury*. Retrieved from http://www.biausa.org/about-brain-injury.htm

Brett, B. L., Gardner, R. C., Godbout, J., Dams-O'Connor, K., & Keene, C. D. (2021). Traumatic brain injury and risk of neurodegenerative disorder. *Biological Psychiatry*, S0006-3223(21)01359-7. https://doi.org/10.1016/j.biopsych.2021.05.025

Bullock, M. R., Merchant, R. E., Choi, S. C., Gilman, C. B., Kreutzer, J. S., Marmarou, A., & Teasdale, G. M. (2002). Outcome measures for clinical trials in neurotrauma. *Journal of Neurosurgery, 13*(1). https://doi.org/10.3171/foc.2002.13.1.6

Bureau of Labor Statistics (BLS), U.S. Department of Labor. (2019). *The Economics Daily*, Barriers to employment for people with a disability. Retrieved from: https://www.bls.gov/opub/ted/2020/barriers-to-employment-for-people-with-a-disability.htm

Burnett, D. M., Kolakowsky-Hayner, S. A., Slater, D., Stringer, A., Bushnik, T., Zafonte, R., & Cifu, D. X. (2003). Ethnographic analysis of traumatic brain injury patients in the national Model Systems database. *Archives of Physical Medicine and Rehabilitation*, *84*(2), 263–267. https://doi.org/10.1053/apmr.2003.50091

Buttorff, C., Ruder, T., & Bauman, M. (2017). *Multiple Chronic Conditions in the United States*. RAND Corporation. https://doi.org/10.7249/TL221

Casagrande, S. S., Gary, T. L., LaVeist, T. A., Gaskin, D. J., & Cooper, L. A. (2007). Perceived discrimination and adherence to medical care in a racially integrated community. *Journal of General Internal Medicine*, *22*(3), 389–395. https://doi.org/10.1007/s11606-006-0057-4

Centers for Disease Control and Prevention, National Center for Health Statistics. (2021, March 26). *Older Persons' Health.* Retrieved from cdc.gov/nchs/fastats/older-american-health.htm

Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. (2021, May 13). *Moderate to severe traumatic brain injury is a lifelong condition.* Retrieved from: www.cdc.gov/TraumaticBrainInjury

Centers for Disease Control and Prevention (2020). *National Diabetes Statistics Report 2020*. Retrieved from https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf.

Centers for Disease Control and Prevention. (2019, March 11). *TBI: Get the Facts | Concussion | Traumatic Brain Injury | CDC Injury Center*. Retrieved from: https://www.cdc.gov/traumaticbraininjury/get_the_facts.html

Centers for Disease Control and Prevention (2019b). Surveillance report of traumatic brain injury-related emergency department visits, hospitalizations, and deaths—United States, 2014. Centers for Disease Control and Prevention, U.S. Department of Health and Human Services.

Centers for Disease Control and Prevention. (2015). *Report to Congress on traumatic brain injury in the United States: Epidemiology and rehabilitation.* National Center for Injury Prevention and Control; Division of Unintentional Injury Prevention.

Centers for Medicare and Medicaid Services (CMS). (2021). Inpatient rehabilitation facility PPS | CMS. Retrieved August 29, 2021, from https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/InpatientRehabFacPPS

Chamberlain, D. J. (2006). The experience of surviving traumatic brain injury. *Journal of Advanced Nursing 54*(4). 407-417.

Chan, V., Sutton, M., Mollayeva, T., Escobar, M. D., Hurst, M., & Colantonio, A. (2020). Data mining to understand how health status preceding traumatic brain injury affects functional outcome: A population-based sex-stratified study. *Archives of Physical Medicine and Rehabilitation*, *101*(9), 1523–1531. https://doi.org/10.1016/j.apmr.2020.05.017

Chang, E. S., Kannoth, S., Levy, S., Wang, S. Y., Lee, J. E., & Levy, B. R. (2020). Global reach of ageism on older persons' health: A systematic review. *PLOS ONE*, *15*(1), e0220857. doi:10.1371/journal.pone.0220857

Cheslock, M., & De Jesus, O. (2021). Presbycusis. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK559220/

Cho, M. J., & Jang, S. H. (2021). Relationship between post-traumatic amnesia and white matter integrity in traumatic brain injury using tract-based spatial statistics. *Scientific Reports*, *11*(1), 6898. https://doi.org/10.1038/s41598-021-86439-0

Cifu, D. X., Kreutzer, J. S., Marwitz, J. H., Rosenthal, M., Englander, J., & High, W. (1996). Functional outcomes of older adults with traumatic brain injury: A prospective, multicenter analysis. *Archives of Physical Medicine and Rehabilitation*, *77*(9), 883–888. https://doi.org/10.1016/S0003-9993(96)90274-9

Connelly J. B., Chell, S., Tennant, A., Rigby, A. S., & Airey, C. M. (2006). Modelling 5-year functional outcome in a major traumatic injury survivor cohort. *Disability and Rehabilitation*, 28 (10), 629–636. doi: 10.1080/09638280500276513

Corrigan, J. D. (1995). Substance abuse as a mediating factor in outcome from traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *76*(4), 302–309. https://doi.org/10.1016/S0003-9993(95)80654-7

Corrigan, J. D., Cuthbert, J. P., Whiteneck, G. G., Dijkers, M. P., Coronado, V., Heinemann, A. W., Harrison-Felix, C., & Graham, J. E. (2012). Representativeness of the Traumatic Brain Injury Model Systems National Database. *The Journal of Head Trauma Rehabilitation*, *27*(6), 391–403. https://doi.org/10.1097/HTR.0b013e3182238cdd

Corrigan, J. D., & Hammond, F. M. (2013). Traumatic brain injury as a chronic health condition. *Archives of Physical Medicine Rehabilitation, 94*(6), 1199-1201. https://doi.org/10.1016/j.apmr.2013.01.023

Corrigan, J. D., Harrison-Felix, C., Bogner, J., Dijkers, M., Terrill, M. S., & Whiteneck, G. (2003). Systematic bias in traumatic brain injury outcome studies because of loss to follow-up. *Archives of Physical Medicine and Rehabilitation*, *84*(2), 153–160. https://doi.org/10.1053/apmr.2003.50093

Corrigan, J. D., Selassie, A. W., Lineberry, L. A., Millis, S. R., Wood, K. D., Pickelsimer, E. E., & Rosenthal, M. (2007). Comparison of the Traumatic Brain Injury (TBI) Model Systems National dataset to a population-based cohort of TBI hospitalizations. *Archives of Physical Medicine and Rehabilitation*, *88*(4), 418–426. https://doi.org/10.1016/j.apmr.2007.01.010

Corrigan, J. D., Smith-Knapp, K., & Granger, C. V. (1997). Validity of the functional independence measure for persons with traumatic brain injury. *Archives of Physical*

Medicine and Rehabilitation, *78*(8), 828–834. https://doi.org/10.1016/S0003-9993(97)90195-7

Crane, P. K., Gibbons, L. E., Dams-O’Connor, K., Trittschuh, E., Leverenz, J. B., Keene, C. D., Sonnen, J., Montine, T. J., Bennett, D. A., Leurgans, S., Schneider, J. A., & Larson, E. B. (2016). Association between traumatic brain injury and late life neurodegenerative conditions and neuropathological findings. *JAMA Neurology*, *73*(9), 1062–1069. https://doi.org/10.1001/jamaneurol.2016.1948

Curzel, J., Forgiarini Junior, L. A., & Rieder, M. de M. (2013). Evaluation of functional independence after discharge from the intensive care unit. *Revista Brasileira de Terapia Intensiva*, *25*(2), 93–98. https://doi.org/10.5935/0103-507X.20130019

Cuthbert, J. P., Corrigan, J. D., Harrison-Felix, C., Coronado, V., Dijkers, M. P., Heinemann, A. W., & Whiteneck, G. G. (2011). Factors That Predict Acute Hospitalization Discharge Disposition for Adults With Moderate to Severe Traumatic Brain Injury. *Archives of Physical Medicine and Rehabilitation*, *92*(5), 721-730.e3. https://doi.org/10.1016/j.apmr.2010.12.023

Cuthbert, J. P., Corrigan, J. D., Whiteneck, G. G., Harrison-Felix, C., Graham, J. E., Bell, J. M., & Coronado, V. G. (2012). Extension of the Representativeness of the Traumatic Brain Injury Model Systems National Database: 2001 to 2010. *The Journal of Head Trauma Rehabilitation*, *27*(6), E15–E27. https://doi.org/10.1097/HTR.0b013e31826da983

Cuthbert, J. P., Harrison-Felix, C., Corrigan, J. D., Kreider, S., Bell, J. M., Coronado, V. G., & Whiteneck, G. G. (2015). Epidemiology of adults receiving acute inpatient rehabilitation for a primary diagnosis of traumatic brain injury in the United States. *The Journal of Head Trauma Rehabilitation*, *30*(2), 122–135. https://doi.org/10.1097/HTR.0000000000000012

Dahdah, M. N., Barnes, S. A., Buros, A., Allmon, A., Dubiel, R., Dunklin, C., Callender, L., & Shafi, S. (2016). The impact of preexisting illness and substance use on functional and neuropsychological outcomes following traumatic brain injury. *Proceedings (Baylor University. Medical Center)*, *29*(3), 271–276. https://doi.org/10.1080/08998280.2016.11929433

Dams-O'Connor, K., Gibbons, L. E., Bowen, J. D., McCurry, S. M., Larson, E. B., & Crane, P. K. (2013). Risk for late-life re-injury, dementia and death among individuals with traumatic brain injury: A population-based study. *Journal of Neurology, Neurosurgery, and Psychiatry*, *84*(2), 177–182. https://doi.org/10.1136/jnnp-2012-303938

Daugherty, J., Waltzman, D., Sarmiento, K., & Xu, L. (2019). Traumatic brain injury–related deaths by race/ethnicity, sex, intent, and mechanism of injury—United States, 2000–2017. *MMWR. Morbidity and Mortality Weekly Report*, *68*. https://doi.org/10.15585/mmwr.mm6846a2

Dodds, T. A., Martin, D. P., Stolov, W. C., & Deyo, R. A. (1993). A validation of the Functional Independence Measurement and its performance among rehabilitation inpatients. *Archives of Physical Medicine and Rehabilitation*, *74*(5), 531–536. https://doi.org/10.1016/0003-9993(93)90119-u

Draper, K., Ponsford, J., & Schonberger, M. (2007). Psychosocial and Emotional Outcomes 10 Years Following Traumatic Brain Injury. *Journal of Head Trauma Rehabilitation Focus on Clinical Research and Practice*, *22*(5), 278–287. https://doi.org/10.1097/01.HTR.0000290972.63753.a7

Eilander, H., Timmerman, R., Scheirs, J., Heugten, C. M., Kort, P., & Prevo, A. (2007). Children and young adults in a prolonged unconscious state after severe brain injury: Long-term functional outcome as measured by the DRS and the GOSE after early intensive neurorehabilitation. *Brain Injury : [BI]*, *21*, 53–61. https://doi.org/10.1080/02699050601151795

English, T., & Carstensen, L. L. (2014). Selective narrowing of social networks across adulthood is associated with improved emotional experience in daily life. *International Journal of Behavioral Development*, *38*(2), 195–202. https://doi.org/10.1177/0165025413515404

Fletcher, J. M., & Frisvold, D. E. (2009). Higher education and health investments: Does more schooling affect preventive health care use? *Journal of Human Capital*, *3*(2), 144–176. https://doi.org/10.1086/645090

Forslund, M. V., Perrin, P. B., Røe, C., Sigurdardottir, S., Hellstrøm, T., Berntsen, S. A., Lu, J., Arango-Lasprilla, J. C., & Andelic, N. (2019). Global outcome trajectories up to 10 years after moderate to severe traumatic brain injury. *Frontiers in Neurology*, *10*. https://doi.org/10.3389/fneur.2019.00219

Forslund, M. V., Roe, C., Perrin, P. B., Sigurdardottir, S., Lu, J., Berntsen, S., & Andelic, N. (2017). The trajectories of overall disability in the first 5 years after moderate and severe traumatic brain injury. *Brain Injury*, *31*(3), 329–335. https://doi.org/10.1080/02699052.2016.1255778

Frankel, J. E., Marwitz, J. H., Cifu, D. X., Kreutzer, J. S., Englander, J., & Rosenthal, M. (2006). A follow-up study of older adults with traumatic brain injury: Taking into account decreasing length of stay. *Archives of Physical Medicine and Rehabilitation*, *87*(1), 57–62. https://doi.org/10.1016/j.apmr.2005.07.309

Gardner, R. C., Burke, J. F., Nettiksimmons, J., Goldman, S., Tanner, C. M., & Yaffe, K. (2015). Traumatic brain injury in later life increases risk for Parkinson's disease. *Annals of Neurology*, *77*(6), 987–995. https://doi.org/10.1002/ana.24396

Gardner, R. C., Dams-O'Connor, K., Morrissey, M. R., & Manley, G. T. (2018). Geriatric traumatic brain injury: Epidemiology, outcomes, knowledge gaps, and future directions. *Journal of Neurotrauma*, *35*(7), 889–906. https://doi.org/10.1089/neu.2017.5371

Gary, K. W., Arango-Lasprilla, J. C., Ketchum, J. M., Kreutzer, J. S., Copolillo, A., Novack, T. A., & Jha, A. (2009). Racial Differences in Employment Outcome After Traumatic Brain Injury at 1, 2, and 5 Years Postinjury. *Archives of Physical Medicine and Rehabilitation*, *90*(10), 1699–1707. https://doi.org/10.1016/j.apmr.2009.04.014

Giovacchini, G., Giovannini, E., Borsò, E., Lazzeri, P., Riondato, M., Leoncini, R., Duce, V., Mansi, L., & Ciarmiello, A. (2019). The brain cognitive reserve hypothesis: A review with emphasis on the contribution of nuclear medicine neuroimaging techniques. *Journal of Cellular Physiology*, *234*(9), 14865–14872. https://doi.org/10.1002/jcp.28308

Godbolt, A. K., Stenberg, M., Lindgren, M., Ulfarsson, T., Lannsjö, M., Stålnacke, B.-M., Borg, J., & DeBoussard, C. N. (2015). Associations between care pathways and outcome 1 year after severe traumatic brain injury. *The Journal of Head Trauma Rehabilitation*, *30*(3), E41-51. https://doi.org/10.1097/HTR.0000000000000050

Green, R. E., Colella, B., Christensen, B., Johns, K., Frasca, D., Bayley, M., & Monette, G. (2008). Examining moderators of cognitive recovery trajectories after moderate to severe traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *89*(12), S16–S24. https://doi.org/10.1016/j.apmr.2008.09.551

Grey, N., & Kennedy, P. (1993). The Functional Independence Measure: A comparative study of clinician and self ratings. *Spinal Cord*, *31*(7), 457–461. https://doi.org/10.1038/sc.1993.74

Guirao, A., Redondo, M., & Artal, P. (2000). Optical aberrations of the human cornea as a function of age. *Journal of the Optical Society of America A, 17*, 1697-1702.

Guo, H. J., & Sapra, A. (2021). Instrumental activity of daily living. In *StatPearls*. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK553126/

Gupte, R. P., Brooks, W. M., Vukas, R. R., Pierce, J. D., & Harris, J. L. (2019). Sex differences in traumatic brain injury: What we know and what we should know. *Journal of Neurotrauma*, *36*(22), 3063–3091. https://doi.org/10.1089/neu.2018.6171

Hammond, F. M., Baker-Sparr, C. A., Dahdah, M. N., Dams-O'Connor, K., Dreer, L. E., O'Neil-Pirozzi, T. M., & Novack, T. A. (2019). Predictors of 1-Year Global Outcomes After Traumatic Brain Injury Among Older Adults: A NIDILRR Traumatic Brain Injury Model Systems Study. *Journal of Aging and Health*, *31*(10_suppl), 68S-96S. https://doi.org/10.1177/0898264318819197

Hammond, F. M., Perkins, S. M., Corrigan, J. D., Nakase-Richardson, R., Brown, A. W., O'Neil-Pirozzi, T. M., Zasler, N. D., & Greenwald, B. D. (2021). Functional change from five to fifteen years after traumatic brain injury. *Journal of Neurotrauma*, *38*(7), 858–869. https://doi.org/10.1089/neu.2020.7287

Haring, R. S., Narang, K., Canner, J. K., Asemota, A. O., George, B. P., Selvarajah, S., Haider, A. H., & Schneider, E. B. (2015). Traumatic brain injury in the elderly: Morbidity and mortality trends and risk factors. *Journal of Surgical Research*, *195*(1), 1–9. https://doi.org/10.1016/j.jss.2015.01.017

Hart, T., Novack, T. A., Temkin, N., Barber, J., Dikmen, S. S., Diaz-Arrastia, R., Ricker, J., Hesdorffer, D. C., Jallo, J., Hsu, N. H., & Zafonte, R. (2016). Duration of Post-Traumatic Amnesia Predicts Neuropsychological and Global Outcome in Complicated Mild Traumatic Brain Injury. *The Journal of Head Trauma Rehabilitation*, *31*(6), E1–E9. https://doi.org/10.1097/HTR.0000000000000210

Harvey, L. A., & Close, J. C. T. (2012). Traumatic brain injury in older adults: Characteristics, causes and consequences. *Injury*, *43*(11), 1821–1826. https://doi.org/10.1016/j.injury.2012.07.188

He, Z., Bian, J., Carretta, H. J., Lee, J., Hogan, W. R., Shenkman, E., & Charness, N. (2018). Prevalence of multiple chronic conditions among older adults in Florida and the United States: Comparative analysis of the OneFlorida Data Trust and National Inpatient Sample. *Journal of Medical Internet Research*, *20*(4), e8961. https://doi.org/10.2196/jmir.8961

Heffernan, D. S., Vera, R. M., Monaghan, S. F., Thakkar, R. K., Kozloff, M. S., Connolly, M. D., Gregg, S. C., Machan, J. T., Harrington, D. T., Adams, C. A. J., & Cioffi, W. G. (2011). Impact of socioethnic factors on outcomes following traumatic brain injury. *Journal of Trauma and Acute Care Surgery*, *70*(3), 527–534. https://doi.org/10.1097/TA.0b013e31820d0ed7

Herou, E., Romner, B., & Tomasevic, G. (2015). Acute Traumatic Brain Injury: Mortality in the Elderly. *World Neurosurgery*, *83*(6), 996–1001. https://doi.org/10.1016/j.wneu.2015.02.023

Hoffman, J. M., Doctor, J. N., Chan, L., Whyte, J., Jha, A., & Dikmen, S. (2003). Potential impact of the new Medicare prospective payment system on reimbursement for traumatic brain injury inpatient rehabilitation. *Archives of Physical Medicine and Rehabilitation*, *84*(8), 1165–1172. https://doi.org/10.1016/S0003-9993(03)00232-6

Hoffman, J. M., Brown, E. D., Chan, L., Dikmen, S., Temkin, N., & Bell, K. R. (2012). Change in inpatient rehabilitation admissions for individuals with traumatic brain injury after implementation of the Medicare Inpatient Rehabilitation Facility Prospective Payment System. *Archives of Physical Medicine and Rehabilitation*, *93*(8), 1305–1312. https://doi.org/10.1016/j.apmr.2012.04.030

Holsinger, T., Steffens, D. C., Phillips, C., Helms, M. J., Havlik, R. J., Breitner, J. C. S., Guralnik, J. M., & Plassman, B. L. (2002). Head injury in early adulthood and the lifetime risk of depression. *Archives of General Psychiatry*, *59*(1), 17–22. https://doi.org/10.1001/archpsyc.59.1.17

Howrey, B. T., Graham, J. E., Pappadis, M. R., Granger, C. V., & Ottenbacher, K. J. (2017). Trajectories of functional change following inpatient rehabilitation for traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *98*(8), 1606–1613. https://doi.org/10.1016/j.apmr.2017.03.009

Ikonomovic, M. D., Mi, Z., & Abrahamson, E. E. (2017). Disordered APP metabolism and neurovasculature in trauma and aging: Combined risks for chronic neurodegenerative disorders. *Ageing Research Reviews*, *34*, 51–63. https://doi.org/10.1016/j.arr.2016.11.003

Jean-Bay, E. (2000). The biobehavioral correlates of post-traumatic brain injury depression. *Journal of Neuroscience Nursing*, *32*(3), 169-176.

Jourdan, C., Bayen, E., Bosserelle, V., Azerad, S., Genet, F., Fermanian, C., Aegerter, P., Pradat-Diehl, P., Weiss, J.-J., & Azouvi, P. (2013). Referral to rehabilitation after severe traumatic brain injury: Results from the Paris-TBI study. *Neurorehabilitation and Neural Repair*, *27*(1), 35–44. https://doi.org/10.1177/1545968312440744

Juengst, S. B., Adams, L. M., Bogner, J. A., Arenth, P. M., O'Neil-Pirozzi, T. M., Dreer, L. E., Hart, T., Bergquist, T. F., Bombardier, C. H., Dijkers, M. P., & Wagner, A. K. (2015). Trajectories of life satisfaction after traumatic brain injury: Influence of life roles, age, cognitive disability, and depressive symptoms. *Rehabilitation Psychology*, *60*(4), 353–364. https://doi.org/10.1037/rep0000056

Karr, J. E., Iverson, G. L., Berghem, K., Kotilainen, A.-K., Terry, D. P., & Luoto, T. M. (2020). Complicated mild traumatic brain injury in older adults: Post-concussion symptoms and functional outcome at one week post injury. *Brain Injury*, *34*(1), 26–33. https://doi.org/10.1080/02699052.2019.1669825

Khan, F., Baguley, I. J., & Cameron, I. D. (2003). 4: Rehabilitation after traumatic brain injury. *Medical Journal of Australia*, *178*(6), 290–295. http://doi.org/kha11095_fm [pii]

Kreutzer, J. S., Marwitz, J. H., & Kepler, K. (1992). Traumatic brain injury: Family response and outcome. *Archives of Physical Medicine and Rehabilitation, 73*(8), 771-778. https://doi.org/10.5555/uri:pii:000399939290213G

Kreutzer, J. S., Wehman, P. H., Harris, J. A., Burns, C. T., & Young, H. F. (1991). Substance abuse and crime patterns among persons with traumatic brain injury referred for supported employment. *Brain Injury*, *5*(2), 177–187. https://doi.org/10.3109/02699059109008088

Lee, Y., Chi, I., & Palinkas, L. A. (2019). Retirement, leisure activity engagement, and cognition among older adults in the United States. *Journal of Aging and Health*, *31*(7), 1212–1234. https://doi.org/10.1177/0898264318767030

Levi Y, Rassovsky Y, Agranov E, Sela-Kaufman M, Vakil E. Cognitive reserve components as expressed in traumatic brain injury. Journal of the International Neuropsychological Society: Journal of the International Neuropsychological Society 2013;19:664–671.

Levin, H. S., Boake, C., Song, J., Mccauley, S., Contant, C., Diaz-Marchan, P., Brundage, S., Goodman, H., & Kotrla, K. J. (2001). Validity and sensitivity to change of the extended Glasgow Outcome Scale in mild to moderate traumatic brain injury. *Journal of Neurotrauma*, *18*(6), 575–584. https://doi.org/10.1089/089771501750291819

Levin, H. S., Temkin, N. R., Barber, J., Nelson, L. D., Robertson, C., Brennan, J., Stein, M. B., Yue, J. K., Giacino, J. T., McCrea, M. A., Diaz-Arrastia, R., Mukherjee, P., Okonkwo, D. O., Boase, K., Markowitz, A. J., Bodien, Y., Taylor, S., Vassar, M. J., Manley, G. T., & TRACK-TBI Investigators. (2021). Association of sex and age with mild traumatic brain injury–related symptoms: A TRACK-TBI study. *JAMA Network Open*, *4*(4), e213046. https://doi.org/10.1001/jamanetworkopen.2021.3046

Liao, C.-C., Chiu, W.-T., Yeh, C.-C., Chang, H.-C., & Chen, T.-L. (2012). Risk and outcomes for traumatic brain injury in patients with mental disorders. *Journal of Neurology, Neurosurgery & Psychiatry*, *83*(12), 1186–1192. https://doi.org/10.1136/jnnp-2012-302337

Linacre, J. M., Heinemann, A. W., Wright, B. D., Granger, C. V., & Hamilton, B. B. (1994). The structure and stability of the functional independence measure. *Archives of Physical Medicine and Rehabilitation*, *75*(2), 127–132. https://doi.org/10.1016/0003-9993(94)90384-0

Liu, H., Yang, Y., Xia, Y., Zhu, W., Leak, R. K., Wei, Z., Wang, J., & Hu, X. (2017). Aging of cerebral white matter. *Ageing Research Reviews*, *34*, 64–76. https://doi.org/10.1016/j.arr.2016.11.006

Lowe, A. J., Paquola, C., Wael, R. V. de, Girn, M., Lariviere, S., Tavakol, S., Caldairou, B., Royer, J., Schrader, D. V., Bernasconi, A., Bernasconi, N., Spreng, R. N., & Bernhardt, B. C. (2019). Targeting age-related differences in brain and cognition with multimodal imaging and connectome topography profiling. *Human Brain Mapping*, *40*(18), 5213–5230. https://doi.org/10.1002/hbm.24767

Lu, J., Roe, C., Sigurdardottir, S., Andelic, N., & Forslund, M. (2018). Trajectory of functional independent measurements during first five years after moderate and severe traumatic brain injury. *Journal of Neurotrauma*, *35*(14), 1596–1603. https://doi.org/10.1089/neu.2017.5299

Madan, A. K., Cooper, L., Gratzer, A., & Beech, D. J. (2006). Ageism in breast cancer surgical options by medical students. *Tennessee Medicine: Journa of the Tennessee Medical Association*, *99*(5), 37-38, 41.

Malaspina, D., Goetz, R. R., Friedman, J. H., Kaufmann, C. A., Faraone, S. V., Tsuang, M., Cloninger, C. R., Nurnberger, J. I., & Blehar, M. C. (2001). Traumatic brain injury and schizophrenia in members of schizophrenia and bipolar disorder pedigrees. *American Journal of Psychiatry*, *158*(3), 440–446. https://doi.org/10.1176/appi.ajp.158.3.440

Marengoni, A., Rizzuto, D., Wang, H.-X., Winblad, B., & Fratiglioni, L. (2009). Patterns of chronic multimorbidity in the elderly population. *Journal of the American Geriatrics Society*, *57*(2), 225–230. https://doi.org/10.1111/j.1532-5415.2008.02109.x

Marquez de la Plata, C. D., Hart, T., Hammond, F. M., Frol, A. B., Hudak, A., Harper, C. R., O'Neil-Pirozzi, T. M., Whyte, J., Carlile, M., & Diaz-Arrastia, R. (2008). Impact of age on long-term recovery from traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *89*(5), 896–903. https://doi.org/10.1016/j.apmr.2007.12.030

Masel, B. E., & DeWitt, D. S. (2010). Traumatic brain injury: A disease process, not an event. *Journal of Neurotrauma*, *27*, 1529-1540.

Mather, M., Scommegna, P., & Kilduff, L. (2019, July). Fact sheet: Aging in the United States. *Population Reference Bureau.* Retrieved from: https://www.prb.org/resources/fact-sheet-aging-in-the-united-states/

Mather, M., & Scommegna, P. (2020, May). The demography of dementia and dementia caregiving. *Population Reference Bureau*. Retrieved from: https://www.prb.org/resources/the-demography-of-dementia-and-dementia-caregiving/

McCauley, S. R., Wilde, E. A., Barnes, A., Hanten, G., Hunter, J. V., Levin, H. S., & Smith, D. H. (2014). Patterns of early emotional and neuropsychological sequelae after mild traumatic brain injury. *Journal of Neurotrauma*, *31*(10), 914–925. https://doi.org/10.1089/neu.2012.2826

McCunniff, P. T., Ramey, J. S., Scott, M. L., Roach, M. J., Vallier, H. A., Moore, T. A., & Kelly, M. L. (2017). Operative versus nonoperative management of civilian gunshot wounds to the spinal cord: Novel use of the functional independence measure for validated outcomes. *World Neurosurgery*, *106*, 240–246. https://doi.org/10.1016/j.wneu.2017.06.132

McHugo, G. J., Krassenbaum, S., Donley, S., Corrigan, J. D., Bogner, J., & Drake, R. E. (2017). The prevalence of traumatic brain injury among people with co-occurring mental health and substance use disorders. *Journal of Head Trauma Rehabilitation*, *32*(3), E65–E74. https://doi.org/10.1097/HTR.0000000000000249

McLean, A. M., Jarus, T., Hubley, A. M., & Jongbloed, L. (2014). Associations between social participation and subjective quality of life for adults with moderate to severe traumatic brain injury. *Disability and Rehabilitation*, *36*(17), 1409–1418. https://doi.org/10.3109/09638288.2013.834986

McMahon, P., Hricik, A., Yue, J. K., Puccio, A. M., Inoue, T., Lingsma, H. F., Beers, S. R., Gordon, W. A., Valadka, A. B., Manley, G. T., Okonkwo, D. O., Casey, S. S., Cooper, S. R., Dams-O'Connor, K., Menon, D. K., Sorani, M. D., Yuh, E. L., Mukherjee, P., Schnyer, D. M., & Vassar, M. J. (2014). Symptomatology and functional outcome in mild traumatic brain injury: Results from the prospective TRACK-TBI study. *Journal of Neurotrauma*, *31*(1), 26–33. https://doi.org/10.1089/neu.2013.2984

McMillan, T. M., Jongen, E. L., & Greenwood, R. J. (1996). Assessment of post-traumatic amnesia after severe closed head injury: Retrospective or prospective? *Journal of Neurology, Neurosurgery & Psychiatry*, *60*(4), 422–427. https://doi.org/10.1136/jnnp.60.4.422

Mellick, D., Gerhart, K. A., & Whiteneck, G. G. (2003). Understanding outcomes based on the post-acute hospitalization pathways followed by persons with traumatic brain injury. *Brain Injury*, *17*(1), 55–71. https://doi.org/10.1080/0269905021000010159

Mikolić, A., van Klaveren, D., Groeniger, J. O., Wiegers, E. J. A., Lingsma, H. F., Zeldovich, M., von Steinbüchel, N., Maas, A. I. R., Roeters van Lennep, J. E., Polinder, S., Åkerlund, C., Amrein, K., Andelic, N., Andreassen, L., Anke, A., Antoni, A., Audibert, G., Azouvi, P., Azzolini, M. L., … Zoerle, T. (2021). Differences between men and women in treatment and outcome after traumatic brain injury. *Journal of Neurotrauma*, *38*(2), 235–251. https://doi.org/10.1089/neu.2020.7228

Molloy, C., Conroy, R. M., Cotter, D. R., & Cannon, M. (2011). Is traumatic brain injury a risk factor for schizophrenia? A meta-analysis of case-controlled population-based studies. *Schizophrenia Bulletin*, *37*(6), 1104–1110. https://doi.org/10.1093/schbul/sbr091

Model Systems Knowledge Translation Center. (2020). The Traumatic Brain Injury Model Systems. Retrieved from https://msktc.org/sites/default/files/2021-DRAFT-TBIMS-Slides-508.pdf

Mosenthal, A. C., Livingston, D. H., Lavery, R. F., Knudson, M. M., Lee, S., Morabito, D., Manley, G. T., Nathens, A., Jurkovich, G., Hoyt, D. B., & Coimbra, R. (2004). The Effect of Age on Functional Outcome in Mild Traumatic Brain Injury: 6-Month Report of a Prospective Multicenter Trial. *Journal of Trauma and Acute Care Surgery, 56*(5), 1042–1048. https://doi.org/10.1097/01.TA.0000127767.83267.33

Moser, C., Spagnoli, J., & Santos-Eggimann, B. (2011). Self-perception of aging and vulnerability to adverse outcomes at the age of 65–70 years. *The Journals of Gerontology: Series B, 66B*(6), 675-680. doi:10.1093/geronb/gbr052

Murphy, S. L., Xu, J., Kochanek, K. D., & Arias, E. (2018). Mortality in the United States, 2017. *NCHS Data Brief, 328.* Retrieved from: cdc_60896_DS1

National Council on Aging (NCO). (2021, January). Get the facts on healthy aging. *Center for Healthy Aging for Professionals.* Retrieved from https://ncoa.org/article/get-the-facts-on-healthy-aging

National Data and Statistical Center (NDSC). (2017, March). *The traumatic brain injury model systems*: *National Institute on Disability, Independent Living, and Rehabilitation Research.* Model Systems Knowledge Translation Center. https://www.tbindsc.org/StaticFiles/Documents/2017_TBIMS_InfoSheet_Brochure.pdf

National Data and Statistical Center (NDSC). (2021). Glasgow Outcome Scale-Extended/GOS-E. *TBINDSC Data Dictionary.* Retrieved from https://hub.tbindsc.org/tbimsdatadictionary/Home

Nelson, L. D., Brett, B. L., Magnus, B. E., Balsis, S., McCrea, M. A., Manley, G. T., Temkin, N., & Dikmen, S. (2020). Functional Status Examination yields higher measurement precision of functional limitations after traumatic injury than the Glasgow Outcome Scale-Extended: A preliminary study. *Journal of Neurotrauma*, *37*(4), 675–679. https://doi.org/10.1089/neu.2019.6719

Nelson, L. D., Ranson, J., Ferguson, A. R., Giacino, J., Okonkwo, D. O., Valadka, A. B., Manley, G. T., & McCrea, M. A. (2017). Validating multi-dimensional outcome assessment using the traumatic brain injury common data elements: An analysis of the TRACK-TBI pilot study sample. *Journal of Neurotrauma*, *34*(22), 3158–3172. https://doi.org/10.1089/neu.2017.5139

Ng, R., Allore, H. G, Monin, J. K., & Levy, B. R. (2016). Retirement as meaningful: Positive retirement stereotypes associated with longevity. *Journal of Social Issues*, *72*(1), 69-85. doi:10.1111/josi.12156

O'Neil, M. E., Carlson, K., Storzbach, D., Brenner, L., Freeman, M., Quiñones, A., Motu'apuaka, M., Ensley, M., & Kansagara, D. (2013). Definition of MTBI from the VA/DOD clinical practice guideline for management of concussion/mild traumatic brain injury (2009). In *Complications of Mild Traumatic Brain Injury in Veterans and Military Personnel: A Systematic Review [Internet]*. Department of Veterans Affairs (US). https://www.ncbi.nlm.nih.gov/books/NBK189784/

Ottenbacher, K. J., Hsu, Y., Granger, C. V., & Fiedler, R. C. (1996). *RC.* The reliability of the Functional Independence Measure: A quantitative review. *Archives of Physical Medicine and Rehabilitation, 77*, 1226-1232.

Parry-Jones, B. L., Vaughan, F. L., & Miles Cox, W. (2006). Traumatic brain injury and substance misuse: A systematic review of prevalence and outcomes research (1994–2004). *Neuropsychological Rehabilitation*, *16*(5), 537–560. https://doi.org/10.1080/09602010500231875

Pedersen, A. R., Stubbs, P. W., & Nielsen, J. F. (2018). Reducing redundant testing using the Functional Independence Measure and Early Functional Abilities scale during rehabilitation in patients with brain injury. *Brain Injury, 32*(9), 1090–1095. https://doi.org/10.1080/02699052.2018.1482425

Plassman, B. L., Havlik, R. J., Steffens, D. C., Helms, M. J., Newman, T. N., Drosdick, D., Phillips, C., Gau, B. A., Welsh-Bohmer, K. A., Burke, J. R., Guralnik, J. M., & Breitner, J. C. (2000). Documented head injury in early adulthood and risk of Alzheimer's disease and other dementias. *Neurology*, *55*(8), 1158–1166. https://doi.org/10.1212/wnl.55.8.1158

Ponsford J, Draper K, Schonberger M. Functional outcome 10 years after traumatic brain injury: Its relationship with demographic, injury severity, and cognitive and emotional status. J Int Neuropsychol Soc. (2008) 14:233–42. doi: 10.1017/S1355617708080272

Prodinger, B., O'Connor, R. J., Stucki, G., & Tennant, A. (2017). Establishing score equivalence of the Functional Independence Measure motor scale and the Barthel Index, utilising the International Classification of Functioning, Disability and Health and Rasch measurement theory. *Journal of Rehabilitation Medicine*, *49*(5), 416–422. https://doi.org/10.2340/16501977-2225

Ranson, J., Magnus, B., Temkin, N., Dikmen, S., Giacino, J., Okonkwo, D., Valadka, A., Manley, G., & Nelson, L. (2019). Diagnosing the GOSE: Structural and psychometric properties using item response theory, a TRACK-TBI pilot study. *Journal of Neurotrauma*, *36*. https://doi.org/10.1089/neu.2018.5998

Ribeiro, D. K. de M. N., Lenardt, M. H., Lourenço, T. M., Betiolli, S. E., Seima, M. D., & Guimarães, C. A. (2018). The use of the Functional Independence Measure in elderly. *Revista Gaúcha de Enfermagem*, *38*. https://doi.org/10.1590/1983-1447.2017.04.66496

Risdall, J. E., & Menon, D. K. (2011). Review. Traumatic brain injury. *Philosophical Transactions of the Royal Society. B* 366, 241–250 http://doi:10.1098/rstb.2010.0230

Roser, M., Ortiz-Ospina, E., & Ritchie, H. (2019). Life expectancy. *Our World in Data.* Retrieved from: https://ourworldindata.org/life-expectancy

Rothweiler, B., Temkin, N. R., & Dikmen, S. S. (1998). Aging effect on psychosocial outcome in traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *79*(8), 881–887. https://doi.org/10.1016/S0003-9993(98)90082-X

Sander, A. (2001). Instructions for rating of Glasgow Outcome Scale-Extended (GOS-E). *Traumatic Brain Injury Model Systems National Data and Statistical Center.* Retrieved from https://tbindsc.org/StaticFiles/Documents/28a_Instructions%20for%20Rating%20GOS-E.pdf.

Sander, A. (2002). The Extended Glasgow Outcome Scale. *The Center for Outcome Measurement in Brain Injury*. http://www.tbims.org/combi/gose/index.html

Sandhaug, M., Andelic, N., Langhammer, B., & Mygland, A. (2015). Functional level during the first 2 years after moderate and severe traumatic brain injury. *Brain Injury*, *29*(12), 1431–1438. https://doi.org/10.3109/02699052.2015.1063692

Scholten, A. C., Haagsma, J. A., Cnossen, M. C., Olff, M., van Beeck, E. F., & Polinder, S. (2016). Prevalence of and risk factors for anxiety and depressive disorders after traumatic brain injury: A systematic review. *Journal of Neurotrauma*, *33*(22), 1969–1994. https://doi.org/10.1089/neu.2015.4252

Schonberger, M., Ponsford, J., Olver, J., Ponsford, M., & Wirtz, M. (2011). Prediction of functional and employment outcome 1 year after traumatic brain injury: A structural equation modeling approach. *Journal of Neurology, Neurosurgery and Psychiatry*, *82*, 936-941.

Seagly, K. S., O’Neil, R. L., & Hanks, R. A. (2018). Pre-injury psychosocial and demographic predictors of long-term functional outcomes post-TBI. *Brain Injury*, *32*(1), 78–83. https://doi.org/10.1080/02699052.2017.1374467

Sendroy-Terrill, M., Whiteneck, G. G., & Brooks, C. A. (2010). Aging with traumatic brain injury: Cross-sectional follow-up of people receiving inpatient rehabilitation over more than 3 decades. *Archives of Physical Medicine and Rehabilitation*, *91*(3), 489–497. https://doi.org/10.1016/j.apmr.2009.11.011

Shafi, S., Marquez de la Plata, C., Diaz-Arrastia, R., Shipman, K., Carlile, M., Frankel, H., Parks, J., & Gentilello, L. M. (2007). Racial disparities in long-term functional outcome after traumatic brain injury. *Journal of Trauma and Acute Care Surgery*, *63*(6), 1263–1270. https://doi.org/10.1097/TA.0b013e31815b8f00

Shiel, A., Burn, J. P., Henry, D., Clark, J., Wilson, B. A., Burnett, M. E., & McLellan, D. L. (2001). The effects of increased rehabilitation therapy after brain injury: Results of a prospective controlled trial. *Clinical Rehabilitation*, *15*(5), 501–514. https://doi.org/10.1191/026921501680425225

Shukla, D., Devi, B. I., & Agrawal, A. (2011). Outcome measures for traumatic brain injury. *Clinical Neurology and Neurosurgery*, *113*(6), 435–441. https://doi.org/10.1016/j.clineuro.2011.02.013

Shumway-Cook, A., Ciol, M. A., Hoffman, J., Dudgeon, B. J., Yorkston, K., & Chan, L. (2009). Falls in the Medicare population: Incidence, associated factors, and impact on health care. *Physical Therapy*, *89*(4), 324–332. https://doi.org/10.2522/ptj.20070107

Sivák, Š., Bittšanský, M., Grossmann, J., Nosál', V., Kantorová, E., Siváková, J., Demková, H. P., & Kurča, E. (2013). Clinical correlations of proton magnetic resonance spectroscopy findings in acute phase after mild traumatic brain injury. *Brain Injury*, *28*(3), 341–346. https://doi.org/10.3109/02699052.2013.865270

Stålnacke, B.-M., Saveman, B.-I., & Stenberg, M. (2019). Long-term follow-up of disability, cognitive, and emotional impairments after severe traumatic brain injury. *Behavioural Neurology*, *2019*, 1–7. https://doi.org/10.1155/2019/9216931

Statista. (2020a). *U.S.: Age distribution*. (n.d.). Statista. Retrieved April 10, 2021, from https://www.statista.com/statistics/270000/age-distribution-in-the-united-states/

Statista. (2020b). *U.S. population by age and gender 2019*. (n.d.). Statista. Retrieved April 10, 2021, from https://www.statista.com/statistics/241488/population-of-the-us-by-sex-and-age/

Stein, M. B., Jain, S., Giacino, J. T., Levin, H., Dikmen, S., Nelson, L. D., Vassar, M. J., Okonkwo, D. O., Diaz-Arrastia, R., Robertson, C. S., Mukherjee, P., McCrea, M., Mac Donald, C. L., Yue, J. K., Yuh, E., Sun, X., Campbell-Sills, L., Temkin, N., Manley, G. T., … Zafonte, R. (2019). Risk of posttraumatic stress disorder and major depression in civilian patients after mild traumatic brain injury: A TRACK-TBI study. *JAMA Psychiatry*, *76*(3), 249–258. https://doi.org/10.1001/jamapsychiatry.2018.4288

Stenberg, M., Godbolt, A. K., Nygren De Boussard, C., Levi, R., & Stålnacke, B.-M. (2015). Cognitive impairment after severe traumatic brain injury, clinical course and impact on outcome: A Swedish-Icelandic study. *Behavioural Neurology*, *2015*, e680308. https://doi.org/10.1155/2015/680308

Stineman, M. G., Shea, J. A., Jette, A., Tassoni, C. J., Ottenbacher, K. J., Fiedler, R., & Granger, C. V. (1996). The functional independence measure: Tests of scaling assumptions, structure, and reliability across 20 diverse impairment categories. *Archives of Physical Medicine and Rehabilitation*, *77*(11), 1101–1108. https://doi.org/10.1016/S0003-9993(96)90130-6

Stocchetti, N., Paternò, R., Citerio, G., Beretta, L., & Colombo, A. (2012). Traumatic Brain Injury in an Aging Population. *Journal of Neurotrauma*, *29*(6), 1119–1125. https://doi.org/10.1089/neu.2011.1995

Stubbs, P., Pallesen, H., Pedersen, A., & Nielsen, J. (2014). Using EFA and FIM rating scales could provide a more complete assessment of patients with acquired brain injury. *Disability and Rehabilitation*, *36*. https://doi.org/10.3109/09638288.2014.904935

Susman, M., DiRusso, S. M., Sullivan, T., Risucci, D., Nealon, P., Cuff, S., Haider, A., & Benzil, D. (2002). Traumatic brain injury in the elderly: Increased mortality and worse functional outcome at discharge despite lower injury severity. *Journal of Trauma and Acute Care Surgery*, *53*(2), 219–224.

Sutin, A. R, Stephan, Y., Carretta, H., & Terracciano, A. Perceived discrimination and physical, cognitive, and emotional health in older adulthood. *The American Journal of Geriatric Psychiatry*, 23(2), 171-179. doi:10.1016/j.jagp.2014.03.007

Sveen, U., Røe, C., Sigurdardottir, S., Skandsen, T., Andelic, N., Manskow, U., Berntsen, S. A., Soberg, H. L., & Anke, A. (2016). Rehabilitation pathways and functional independence one year after severe traumatic brain injury. *European Journal of Physical and Rehabilitation Medicine*, *52*(5), 12.

Tate, R. L., & Broe, G. A. (1999). Psychosocial adjustment after traumatic brain injury: What are the important variables? *Psychological Medicine*, *29*(3), 713–725. https://doi.org/10.1017/S0033291799008466

Tate, R. L., Lulham, J. M., Broe, G. A., Strettles, B., & Pfaff, A. (1989). Psychosocial outcome for the survivors of severe blunt head injury: The results from a consecutive series of 100 patients. *Journal of Neurology, Neurosurgery & Psychiatry*, *52*(10), 1128–1134. https://doi.org/10.1136/jnnp.52.10.1128

Teasdale, G., & Jennett, B. (1974). Assessment of coma and impaired consciousness. *The Lancet*, *304*(7872), 81–84. https://doi.org/10.1016/s0140-6736(74)91639-0

Testa, J. A., Malec, J. F., Moessner, A. M., & Brown, A. W. (2005). Outcome after traumatic brain injury: Effects of aging on recovery. *Archives of Physical Medicine and Rehabilitation*, *86*(9), 1815–1823. https://doi.org/10.1016/j.apmr.2005.03.010

Theadom, A., Parag, V., Dowell, T., McPherson, K., Starkey, N., Barker-Collo, S., Jones, K., Ameratunga, S., Feigin, V. L., & BIONIC Research Group. (2016). Persistent problems 1 year after mild traumatic brain injury: a longitudinal population study in New Zealand. *British Journal of General Practice*, *66*(642), e16–e23. https://doi.org/10.3399/bjgp16x683161

Thompson, H. J., Dikmen, S., & Temkin, N. (2012). Prevalence of comorbidity and its association with traumatic brain injury and outcomes in older adults. *Research in Gerontological Nursing*, *5*(1), 17–24. https://doi.org/10.3928/19404921-20111206-02

Thompson, H. J., Rivara, F., Becker, K. J., Maier, R., & Temkin, N. (2020). Impact of aging on the immune response to traumatic brain injury (AIm:TBI) study protocol. *Injury Prevention*, *26*, 471–477. https://doi.org/10.1136/injuryprev-2019-043325

Toosi, M. & Torpey, E. (May 2017). Older workers: Labor force trends and career options. *Career Outlook, U. S. Bureau of Labor Statistics.* https://www.bls.gov/careeroutlook/2017/article/older-workers.htm

Traumatic Brain Injury Model Systems Program. (2018). Traumatic Brain Injury Model Systems National Database. *Traumatic Brain Injury Model Systems National Data and Statistical Center*. https://doi.org/10.17605/osf.io/a4xzb

Utomo, W. K., Gabbe, B. J., Simpson, P. M., & Cameron, P. A. (2009). Predictors of in-hospital mortality and 6-month functional outcomes in older adults after moderate to severe traumatic brain injury. *Injury*, *40*(9), 973–977. https://doi.org/10.1016/j.injury.2009.05.034

Vale, M. T., Bisconti, T. L., & Sublett, J. F. (2020). Benevolent ageism: Attitudes of overaccommodative behavior toward older women. *The Journal of Social Psychology*, 160(5), 548-558. doi:10.1080/00224545.2019.1695567

van den Akker, M., Buntinx, F., & Knottnerus, J. A. (1996). Comorbidity or multimorbidity. *European Journal of General Practice*, *2*(2), 65–70. https://doi.org/10.3109/13814789609162146

Vanderploeg, R. D., Curtiss, G., Duchnick, J. J., & Luis, C. A. (2003). Demographic, medical, and psychiatric factors in work and marital status after mild head injury. *The Journal of Head Trauma Rehabilitation*, *18*(2), 148–163.

Vassallo, J. L., Proctor-Weber, Z., Lebowitz, B. K., Curtiss, G., & Vanderploeg, R. D. (2007). Psychiatric risk factors for traumatic brain injury. *Brain Injury*, *21*(6), 567–573. https://doi.org/10.1080/02699050701426832

Vespa, J., Medina, L., & Armstrong, D. M. (February, 2020). Demographic turning points for the United States: Population projections for 2020 to 2060. *U.S. Department of Commerce, U. S. Census Bureau: Current Population Reports*, 25-1144. https://www.census.gov/content/dam/Census/library/publications/2020/demo/p25-1144.pdf

Vollmer, D. G., Torner, J. C., Jane, J. A., Sadovnic, B., Charlebois, D., Eisenberg, H. M., Foulkes, M. A., Marmarou, A., & Marshall, L. F. (1991). Age and outcome following traumatic coma: Why do older patients fare worse? *Journal of Neurosurgery*, *75*(Supplement), S37–S49. https://doi.org/10.3171/sup.1991.75.1s.0s37

von Steinbuechel, N., Covic, A., Polinder, S., Kohlmann, T., Cepulyte, U., Poinstingl, H., Backhaus, J., Bakx, W., Bullinger, M., Christensen, A.-L., Formisano, R., Gibbons, H., Höfer, S., Koskinen, S., Maas, A., Neugebauer, E., Powell, J., Sarajuuri, J., Sasse, N., Schmidt, S., Muhlan, H., von Wild, K., Zitnay, G., & Truelle, J.-L. (2016). Assessment of health-related quality of life after TBI: Comparison of a disease-specific (QOLIBRI) with a generic (SF-36) instrument. *Behavioural Neurology*, *2016*, e7928014. https://doi.org/10.1155/2016/7928014

Wäljas, M., Iverson, G., Lange, R., Hakulinen, U., Dastidar, P., Huhtala, H., Liimatainen, S., Hartikainen, K., & Ohman, J. (2014). A prospective biopsychosocial study of the persistent post-concussion symptoms following mild traumatic brain injury. *Journal of Neurotrauma*, *32*. https://doi.org/10.1089/neu.2014.3339

Wang, D., Xing, X.-H., & Wu, X.-B. (2013). Healthy lifestyles of university students in china and influential factors. *The Scientific World Journal*, *2013*, e412950. https://doi.org/10.1155/2013/412950

Weil, Z. M., Corrigan, J. D., & Karelina, K. (2018). Alcohol use disorder and traumatic brain injury. *Alcohol Research: Current Reviews*, *39*(2), 171–180.

Willemse-van Son, A. H. P., Ribbers, G. M., Verhagen, A. P., & Stam, H. J. (2007). Prognostic factors of long-term functioning and productivity after traumatic brain injury: A systematic review of prospective cohort studies. *Clinical Rehabilitation*, *21*(11), 1024–1037. https://doi.org/10.1177/0269215507077603

Williams, H., Caplan, B., Bogner, J., Brenner, L., Perrin, P. B., Niemeier, J. P., Mougeot, J.-L., Vannoy, C. H., Hirsch, M. A., Watts, J. A., Rossman, W., Grafton, L. M., Guerrier, T. D., Pershad, R., Kingsbury, C. A., Bartel, S. W., & Whitney, M. P. (2015). Measures of Injury Severity and Prediction of Acute Traumatic Brain Injury Outcomes. *Journal of Head Trauma Rehabilitation*, *30*(2), 136–142. https://doi.org/10.1097/HTR.0000000000000026

Wilson, J. T. L., Pettigrew, L. E. L., & Teasdale, G. M. (1998). Structured interviews for the Glasgow Outcome Scale and the Extended Glasgow Outcome Scale: Guidelines for their use. *Journal of Neurotrauma*, *15*(8), 573–585. https://doi.org/10.1089/neu.1998.15.573

Wilson, J. T. L., Pettigrew, L. E. L., & Teasdale, G. M. (2000). Emotional and cognitive consequences of head injury in relation to the Glasgow Outcome Scale. *Journal of*

Neurology, Neurosurgery & Psychiatry, *69*(2), 204–209. https://doi.org/10.1136/jnnp.69.2.204

Wilson, R. S., Yu, L., Lamar, M., Schneider, J. A., Boyle, P. A., & Bennett, D. A. (2019). Education and cognitive reserve in old age. *Neurology*, *92*(10), e1041–e1050. https://doi.org/10.1212/WNL.0000000000007036

Winter, D. A., Patla, A. E., Frank, J. S., & Walt, S. E. (1990). Biomechanical walking pattern changes in the fit and healthy elderly. *Pyshical Therapy, 70,* 340-347.

Wong, J. S., & Waite, L. J. (2015). Marriage, social networks, and health at older ages. *Journal of Population Ageing*, *8*(1), 7–25. https://doi.org/10.1007/s12062-014-9110-y

Wood, R. L., & Yurdakul, L. K. (1997). Change in relationship status following traumatic brain injury. *Brain Injury*, *11*(7), 491–501. https://doi.org/10.1080/bij.11.7.491.501

World Health Organization (2019). Life expectancy and healthy life expectancy. *The Global Health Observatory.* Retrieved August 29, 2021, from https://www.who.int/data/maternal-newborn-child-adolescent-ageing/advisory-groups/gama/gama-advisory-group-members

Worldometer. (2021). United States population (2021). Retrieved April 10, 2021, from https://www.worldometers.info/world-population/us-population/

Worldometer. (2020). World population (2020 and historical). Retrieved August 29, 2021, from https://www.worldometers.info/world-population/#growthrate

Wyman, M., Shiovitz-Ezra, S., & Bengel, J. (2018). Ageism in the health care system: Providers, patients, and systems. In L. Ayalon & C. Tesch-Römer (Eds.), *Contemporary perspectives on ageism* (Vol. 19). Springer International Publishing. doi:10.1007/978-3-319-73820-8

Yap, S. G. M., & Chua, K. S. G. (2008). Rehabilitation outcomes in elderly patients with traumatic brain injury in Singapore. *Journal of Head Trauma Rehabilitation*, *23*(3), 158–163. https://doi.org/10.1097/01.HTR.0000319932.15085.fe

Zuercher, M., Ummenhofer, W., Baltussen, A., & Walder, B. (2009). The use of Glasgow Coma Scale in injury assessment: A critical review. *Brain Injury*, *23*(5), 371–384. https://doi.org/10.1080/02699050902926267