DISSERTATION

ACUTE CARE REHABILITATION UTILIZATION, ACCESS, AND OUTCOMES AMONG HOSPITALIZED ADULTS WITH TRAUMATIC BRAIN INJURY

Submitted by

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ABSTRACT

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Objective: The purpose of this dissertation was to conduct three research studies aimed at gaining a comprehensive understanding of the barriers and facilitators to equitable access to and timing of rehabilitation services, community discharge, and unplanned 90-day post-discharge hospital readmission among individuals hospitalized with Traumatic brain injury (TBI).
Introduction: There are approximately 2.5 million TBI-related emergency department visits, 288,000 TBI-related hospitalizations, and 61,000 TBI-related deaths reported each year (Center for Disease Control and Prevention, 2019). TBI is associated with high rates of disability, including limitations in performing basic activities of daily living (ADLs), such as self-care, and/or in performing physical tasks, such as mobility (Klima et al., 2019; Jessica Lo et al., 2021; Whiteneck et al., 2016). Individuals who are hospitalized with TBI should receive equitable access to multidisciplinary care, including rehabilitation services (occupational therapy [OT], and physical therapy [PT]) to address potential self-care issues, physical limitations, and cognitive deficits (National Academies of Sciences & Medicine, 2022). Early onset of acute care rehabilitation services can have positive long-term benefits for patients, including improved function, increased mobility, and enhanced quality of life (Andelic et al., 2012; Bernhardt et al., 2017; C. Y. Wang et al., 2021). A primary focus of acute care rehabilitation services is to improve patients' functional performance (Ejlersen Wæhrens & Fisher, 2007). Following acute care stays, community discharge is generally viewed as quality care indicator in acute care

settings (Department of Health and Human Services [HHS], 2019). Readmission is a common concern for those who have chronic illnesses or injuries, and it is associated with higher healthcare expenses and lower quality of care (Jencks et al., 2009). Readmission rates after TBI contribute considerably to these costs, making lowering readmission rates a universal goal (Canner et al., 2016). Despite research advances and policy changes, barriers and challenges remain facing individuals with TBI (National Academies of Sciences & Medicine, 2022). Not all individuals with TBI have early access to rehabilitation services, are discharged to the community, or can avoid hospital readmission. Although several studies have addressed these issues in general population, variability in community and personal level factors among individuals with TBI need to be addressed (Office of Disease Prevention and Health Promotion & Services., 2020). Therefore, these dissertation studies are aimed at providing empirical support, further understanding, and increasing our knowledge around factors that influence individuals with TBI acute care rehabilitation services utilization and outcomes.

Method: This dissertation is comprised of three studies. In Study One, we investigated how Social Determinants of Health (SDoH) impact access to and timing of rehabilitation services. Multivariable logistic and Cox regression analyses (i.e., time-to-event analyses) were used to calculate odds ratios for the likelihood of receiving OT and PT services, and hazard ratios for the duration to initiation of services among those who received these services. In Study Two, we explored whether the relationship between acute care OT/PT utilization and community discharge is moderated by functional or physical performance at discharge. Multivariable moderation logistic regression models were used to calculate odds ratios for the likelihood of community discharge among those who utilized OT/PT services. In both OT and PT models, we computed the main effect of OT/PT utilization on community discharge, the main effect of

functional/physical (ADL/Mobility) performance scores at discharge on community discharge, and the moderating effect of ADL/mobility scores on the relationship between OT/PT utilization and community discharge. In Study Three, we examined the association between discharge functional status and unplanned hospital readmission. Logistic regression was performed to calculate odds ratios for the likelihood of unplanned 90-day hospital readmission among those who received rehabilitation services during their acute care stay.

Results: In Study One, all community-level SDoH such as education attainment, income, and rurality did not show significant associations with access to or timing of acute rehabilitation services (*p*-values= 0.09 – 0.95). In Study Two, both ADL/mobility performance scores at discharge significantly moderated the relationship between OT/PT utilization and community discharge (ORs= 0.99, 95% CIs [0.98, 1.00]). In Study Three, neither discharge functional nor mobility scores were associated with readmission (*p*-values= 0.14 – 0.17). Among the three dissertation studies, several covariates such as age, presence of a significant other, race/ethnicity, health insurance type, TBI severity, length of stay, and comorbidity burden showed significant associations with access to or timing of acute rehabilitation services, community discharge, and readmission status (*p*-values= 0.04 – <0.001).

Conclusion: Further investigations are needed to 1) ascertain whether our community-level SDoH variables, based on the first three digits of zip codes, adequately capture individual experiences and their impact on healthcare, or if community-level education, income, and rurality genuinely do not affect access to and timing of therapy services for hospitalized patients with TBI; 2) determine whether the consideration of ADL/mobility scores at discharge alone limits our understanding of the relationship, failing to encompass other patient-level factors that could either facilitate or impede a safe community discharge; and 3) determine whether

discharge functional and mobility scores were too restrictive in capturing the full benefits of acute care rehabilitation services in reducing the risk of unplanned 90-day readmission risk in hospitalized patients with TBI.

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DEDICATION

With deep gratitude, this dissertation is dedicated to my beloved family, my wife, Rana, and my children, Kenan and Anmar. Your support and understanding have been my guiding light throughout this transformative journey. To my father, Abduljabbar, my mother, Zainab, and my sisters, Sabah, Rawan, and Razan—your boundless love, constant encouragement, and selfless sacrifices have fueled my aspirations. This work stands as a tribute to the collective love, support, and efforts of those who have played pivotal roles in shaping my academic path. May it serve as a long-lasting expression of appreciation for the immeasurable contributions of those who have stood steadfastly by my side.

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CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

Traumatic Brain Injury Prevalence and Clinical Presentation

Traumatic brain injury (TBI) refers to an injury that causes abnormal brain function and can result from blunt or penetrating trauma, acceleration/deceleration forces, or explosive blasts (Brito et al., 2019). TBI is a pressing public health concern in the US, with approximately 2.5 million TBI-related emergency department visits, 288,000 TBI-related hospitalizations, and 61,000 TBI-related deaths reported each year (Centers for Disease Control and Prevention, 2019). The cost of caring for TBI is also high, at approximately $3.2 billion per year (Russo. A & Steiner. C, 2007). Additionally, the economic cost of TBI in the US is estimated at $60 billion per year, including direct costs of follow-up medical services and indirect economic costs, such as lost wages (Seifert, 2007).

There are three levels of TBI classification: mild, moderate, or severe, based on multiple clinical findings, including an individual's persistent signs and symptoms (Olson-Madden et al., 2012). TBI symptoms vary according to the severity of the injury. While some symptoms may resolve, others might persist and cause partial or complete permanent disabilities (Olson-Madden et al., 2012).

TBI can have substantial impacts on an individual's functions, physical activities, emotions, cognition, and socialization (Hawthorne et al., 2009). TBI is associated with high rates of disability, including limitations in performing basic activities of daily living (ADLs), such as self-care, and/or in performing physical tasks, such as mobility (Klima et al., 2019; Jessica Lo et al., 2021; Whiteneck et al., 2016). Along with acute medical complications that are associated with TBI, patients may experience long-term effects such as behavioral, cognitive, physical, and

emotional deficits and limitations that make them more vulnerable for recurrent acute medical complications (Brito et al., 2019). Common cognitive dysfunction includes problems with attention, information processing, executive functions, language, learning and memory (Arciniegas et al., 2002; de Freitas Cardoso et al., 2019). TBI is widely recognized as a chronic condition with various accompanying complications which can negatively affect one's quality of life (Gorgoraptis et al., 2019; Jennifer Fleming, 1999). TBI is a persistently disabling condition that requires multi-faceted intervention strategies for successful recovery and return to community, work, school, and normal daily activities (Corrigan & Hammond, 2013; Hoge et al., 2008).

Individuals with TBI require acute care and should receive high quality multidisciplinary health care, including rehabilitation services (occupational therapy [OT], and physical therapy [PT]), that address self-care issues, physical limitations, and cognitive deficits (National Academies of Sciences & Medicine, 2022). In acute care settings, rehabilitation practitioners use the Activity Measure for Post-Acute Care (AM-PAC^{TM}) "6-Clicks" daily activity inpatient short forms to measure ADLs and basic mobility scores at admission and discharge (Jette et al., 2014). The AM-PAC "6-Clicks" is a valid measure that predicts discharge disposition following acute care stays (Jette et al., 2014).

OT practitioners rate the following ADLs according to level of assistance needed on a scale of 1 ("total") to 4 ("none"): upper body dressing, lower body dressing, bathing, toileting, grooming, and eating (Jette et al., 2014). PT practitioners rate the following activities of physical performance according to level of assistance needed on a scale of 1 ("total") to 4 ("none"): bed mobility, sit to stand, supine to sit, seated transfers, ambulation, and ascending stairs (Jette et al., 2014). The AM-PAC "6-Clicks" has very high internal consistency among OT and PT

practitioners: Cronbach's alpha = 0.91and 0.96 for ADL and mobility assessments, respectively (Jette et al., 2014). The AM-PAC "6-Clicks" scores are standardized (Jette et al., 2014), with higher scores indicating greater ADL performance (range = 17.07 – 57.54), as well as greater basic mobility abilities (range = 23.55 – 61.14).

Pre-existing conditions (comorbidities) can also influence a TBI survivor's evaluation, treatment, progress, prognosis, related discharge planning process and readmission status (Hammond et al., 2019; Hammond et al., 2015; Harrison-Felix et al., 2015; Hoffman et al., 2020). To address the impact of comorbidity burden on patients hospitalized with TBI, several indices have been developed including Charlson Comorbidity Index (CCI), The Elixhauser Comorbidity Index, and Functionally relevant TBI Comorbidity Index [Fx-TBI-CI]. Both the CCI and ECI were developed in non-TBI patient populations and were related to mortality or healthcare utilization, not functioning, and notably exclude conditions known to co-occur with TBI (Kumar et al., 2022). In 2022, the Fx-TBI-CI was developed to categorize comorbidities in patients with TBI based on ICD diagnosis codes obtained from hospital administrative data (Kumar et al., 2022). The Fx-TBI-CI was calibrated based on the function of individuals with TBI receiving inpatient care (Kumar et al., 2022). The Fx-TBI-CI outperformed the ECI in predicting post-discharge functional status in patients with TBI (Kumar et al., 2022).

IMPACT OF INDIVIDUAL CHARACTERISTICS ON TBI ACUTE CARE EXPERIENCES

Various studies have indicated that patient-level factors including age, sex, significant other status, ethnicity, type of healthcare insurance, injury severity levels, and number of comorbidities can negatively impact the quality of rehabilitation services received, discharge location, and readmission status among individuals with musculoskeletal, oncologic, and other

disabling conditions (E. Carvalho et al., 2017; Oyesanya, Harris, Yang, et al., 2021; Zhang et al., 2018). In the following paragraphs, I will go into further details to explain the impact of these individual characteristics on select patient outcomes.

Age

Throughout the literature, age is consistently associated with patient outcomes, including access to healthcare services, discharge location, and unplanned readmission (Brown et al., 2012; Hao et al., 2020; Oyesanya, 2020; Oyesanya, Harris, Cary, et al., 2021; Zhang et al., 2018). Some have reported that older patients are more likely to have early access to rehabilitation services compared to their younger counterparts (Hao et al., 2020; Hargreaves et al., 2015; Robards et al., 2019; Zhang et al., 2018). Prior studies also showed that older patients are more likely to discharge to healthcare facilities rather than home compared to their younger counterparts (Brown et al., 2012; Oyesanya, 2020; Oyesanya, Harris, Cary, et al., 2021; Zhang et al., 2018). Several studies have identifies that older patients with TBI experience a higher likelihood of being readmitted to the hospital (Brito et al., 2019; Brown et al., 2021; Canner et al., 2016; Gardner et al., 2018; Hammond et al., 2015; Ho et al., 2019; Hoffman et al., 2020; Hsia. RY et al., 2018; Li et al., 2018; Saverino et al., 2016; Wasfie. T et al., 2020). These consistent findings may be due to various factors that often accompany aging such as changes in health insurance type (e.g., Medicare), social support, and comorbid health conditions.

Sex

The literature is mixed on the relationship between patients' sex and access to healthcare services, discharge location, and unplanned readmission (Alvi et al., 2019; Brown et al., 2021; Elsamadicy et al., 2017; Ho et al., 2019; Lippa et al., 2018; Mikolic et al., 2021; Vorasubin et al., 2018; Zarshenas et al., 2019). While some studies found that female patients were more likely to

have better access to healthcare services and outcomes (Alvi et al., 2019; Jacob et al., 2020; Lippa et al., 2018), others revealed that male patients were more likely to experience better access to healthcare services and outcomes (Elsamadicy et al., 2017; Vorasubin et al., 2018).

In terms of discharge location, some report that females with mild TBI were more likely to be discharged home compared to males (Huang et al., 2019; Mikolic et al., 2021; Mikolić et al., 2020). Other indicated that females were more likely to discharge to other facilities such as rehabilitation facilities rather than home compared to males (Lu et al., 2022; Zarshenas et al., 2019). In terms of readmission status, more recent studies support that males have greater likelihood of being readmitted over females (Brown et al., 2021; Ho et al., 2019; Li et al., 2018; Saverino et al., 2016); however, one study concluded that sex has no influence on readmission status (Gardner et al., 2018). This inconsistency may be due to several factors related to sex differences. For instance, males and females perceive health, pain, and disability differently (Lippa et al., 2018; Ottochian et al., 2009). In particular, the individual's sex is likely to influence their choice of health care facilities and providers, which subsequently may positively or negatively impact outcomes (Manandhar et al., 2018).

Significant Other Status

Previous research indicated that patients who have a significant other (i.e., a spouse or caregiver) are more likely to have better access to healthcare services, discharge to the community, and less likely to experience unplanned readmission (Albrecht et al., 2017; Hao et al., 2020; Lin et al., 2022; Owolabi et al., 2023; Rodakowski et al., 2017; Schultz et al., 2022; Torbica et al., 2015; Wolff et al., 2020). Patients with a significant other may have physical, social, and mental support (Wolff et al., 2020), which may influence all three aforementioned healthcare outcomes.

Several studies reported that presence of a significant other may affect patients' decision in selecting a facility, providers, or access to healthcare services (Rodakowski et al., 2017; Torbica et al., 2015; Wolff & Roter, 2011). Recent studies revealed that patients with social support (i.e., spouse, family, friends) are more likely to discharge home compared to those without support (Bukhari et al., 2021; Chevalley et al., 2022; Eum et al., 2017; Rodakowski et al., 2017; Souesme et al., 2022). Prior research also demonstrates that patients with significant others are less likely to experience unplanned readmissions (Cakir et al., 2017; Lin et al., 2022; Schultz et al., 2022). Research showed that patients with a significant other are more likely to have positive outcomes (e.g., better engagement in therapeutic session and greater community integration) and overall satisfaction compared to those without (Sander et al., 2012; Yasmeen et al., 2020). Overall, the influence of having a significant other on access to healthcare services, discharge disposition, and unplanned readmission rate could be related to patients' goals, preferences for post-acute care, and treatment planning (HHS., 2019)

Race and Ethnicity

Studies on racial/ethnic disparities in healthcare access and outcomes (e.g., community discharge and unplanned readmission) are abundant in the literature. A number of studies showed that non-ethnic or non-racial minority patients are more likely to obtain high quality health care and rehabilitation services compared with racial/ethnic minorities (Albright et al., 2020; Cancel-Tirado et al., 2018; Meagher et al., 2015; Schoenfeld et al., 2019). Disparities in access to health care services among different ethnic groups may be due to several determinants such as low income, lack of health insurance, and low education (Cancel-Tirado et al., 2018; Meagher et al., 2015). Because of previously mentioned factors, racial minority patients experience limited access to receiving high quality health care and rehabilitation services in any

settings compared to non-racial minorities (Albright et al., 2020; Cancel-Tirado et al., 2018; Gao et al., 2018; Keeney et al., 2017a; Meagher et al., 2015; Schoenfeld et al., 2019).

On the other hand, research on ethnic or racial minority patients with TBI reported that those patients are more likely to be discharged to the community relative to their non-ethnic minority counterparts (Brenner et al., 2020; Chevalley et al., 2022; Kane et al., 2014; Lu et al., 2022; Meagher et al., 2015). However, a recent study on individuals with TBI revealed the contrary, with ethnic or racial minority patients being more likely to be discharged to inpatient rehabilitation facilities than non-racial minority patients (Vadlamani et al., 2019). Another recent study indicated that there are no differences between Black and White patients in regard discharge to facility vs. home (Warren & García, 2022).

Regarding readmission status, one study on ethnic or racial minority patients showed that Black patients have greater likelihood of being readmitted over Hispanic and non-Hispanic White patients (Hsia. RY et al., 2018). The effect of ethnic minority status on discharge disposition and readmission status may be due to social or cultural differences (Bowman et al., 2007; Jacobs et al., 2006). As a result, non-racial minority patients will have better outcomes and overall satisfaction compared to racial minority patients (Flores et al., 2020; Keeney et al., 2017b; Odonkor et al., 2021).

Health Insurance Type

Prior studies revealed that patients with public health insurance (i.e., Medicare / Medicaid) are less likely to have early access to healthcare services, less likely to be discharged to the community, and more likely to be readmitted to the hospital following discharge than patients with private health insurance (Alcalá et al., 2018; Brito et al., 2019; Brown et al., 2021; Bukhari et al., 2022; Saposnik et al., 2008; Sorensen et al., 2020). In addition, patients with

Medicaid insurance or no insurance are less likely to have early access to healthcare services (Albrecht et al., 2017; Alcalá et al., 2018; Gao et al., 2018).

Patients with public health insurance are also less likely to discharge to the community (Kane et al., 2014; Lu et al., 2022). Furthermore, when comparing readmission rates among individuals with different types of public health insurance, one study found that Medicaid patients are more likely to be readmitted than Medicare patients (Hsia. RY et al., 2018), whereas other studies showed that Medicare patients have the highest readmission rates (Hoffman et al., 2020; Li et al., 2018). The influence of insurance types may be related to patients' socioeconomic status which impacts access, discharge disposition, and readmission (Li et al., 2018; Lu et al., 2022; Saposnik et al., 2008).

Injury Severity level and Comorbid Conditions

Patients with greater injury severity and comorbidity burden have higher likelihoods of early access to healthcare services, lower likelihood to be discharged to the community, and higher likelihood to be readmitted (Brenner et al., 2020; Brown et al., 2021; Canner et al., 2016; Ho et al., 2019; Hoffman et al., 2020; Huang et al., 2019; Jacob et al., 2020; Karr et al., 2021; Lu et al., 2022; Sastry et al., 2022; Saverino et al., 2016; Zatzick et al., 2017). However, one study indicated that comorbid conditions were not associated with readmission status (Wasfie. T et al., 2020). Regarding TBI severity, (Hsia. RY et al., 2018) reported that patients with mild TBI were more likely to be readmitted over moderate and severe TBI, whereas other authors concluded that more severe TBI cases were more likely to be readmitted over mild ones (Hoffman et al., 2020; Li et al., 2018; Saverino et al., 2016; Tran et al., 2017).

IMPACTS OF SOCIAL DETERMINANTS OF HEALTH (SDOH) ON TBI ACUTE CARE EXPERIENCES

Recent research has also suggested that SDoH factors including median income, educational levels, and residence location can affect both access to care and post-hospitalization outcomes for individuals with disabling injuries or medical conditions (Brown et al., 2021; Groysman et al., 2022; Huang et al., 2019; Jacob et al., 2020; Megan, 2021; Thorne et al., 2022; Towne et al., 2021).Below, I provide examples from the recent research.

Median Income

Evidence from the literature suggests that an individual's median income influences access to high-quality health care, discharge to the community, and the prevention of unexpected readmission (Brown et al., 2021; Chokshi, 2018; Frier et al., 2017; Huang et al., 2019). Meaning that, patients with higher median income are more likely to have higher quality health care services (Albrecht et al., 2017; Cherla et al., 2018; Chokshi, 2018; Eliacin et al., 2022; Frier et al., 2017; Hao et al., 2020; Owolabi et al., 2023; Thorne et al., 2022; Yue et al., 2020). In contrast, patients with lower median income are less likely to discharge to community and more likely to be readmitted compared to those with high income (Brown et al., 2021; Groysman et al., 2022; Huang et al., 2019; Lueckmann et al., 2021).

People with higher income are more likely to have more education, reside in urban areas, and have private insurance (Groysman et al., 2022; Lai et al., 2020). Individuals with higher income have more available resources, enabling them to access better health care facilities and providers (Ford et al., 2018; Groysman et al., 2022). Higher median income individuals may have primary care providers that monitor their health status and provide them with the required health care services related to their health issues (Ford et al., 2018; Lueckmann et al., 2021). As a

result of using high quality facilities and providers, individuals with higher median incomes will likely experience better outcomes and overall health (Haines et al., 2019; Somrongthong et al., 2017).

Educational Level

The impact of individuals' educational attainment on healthcare access, discharge destination, and readmission has been extensively researched in the literature. Patients with higher educational attainment were more likely to receive high-quality health-care services, be discharged to the community, and have fewer unplanned readmissions (Brown et al., 2021; Huang et al., 2019; Jacob et al., 2020; Raghupathi & Raghupathi, 2020; Thorne et al., 2022; Zajacova & Lawrence, 2018). Higher educational attainment has been associated with improved income, higher health literacy, better living conditions, and more resources (Frier et al., 2017; Robards et al., 2019). Compared to those with low health literacy, persons with higher educational attainment are more likely to select high-quality health care facilities and providers (Jacob et al., 2020; Raghupathi & Raghupathi, 2020; Thorne et al., 2022). Individuals with higher education are more likely to know about their rights as patients and select health care services that are appropriate for their health conditions (Campbell et al., 2018). For these reasons, research showed that individuals with higher educational attainment are more likely to have better health related outcome including longer life expectancy and fewer associated comorbidities (Health, 2020).

Residence Location

Several studies found that patients living in urban areas relative to those living in rural areas are more likely to have early access to health care services, be discharged home, and less likely to be readmitted (Cancel-Tirado et al., 2018; Graves et al., 2019; Hao et al., 2020; Huang

et al., 2019; Megan, 2021; Saverino et al., 2016; Yue et al., 2020). Living in urban areas has been associated with better living situation, accessible resources (e.g., reliable transportation system), and more high-quality health care facilities and provides (Cyr et al., 2019; Henning-Smith et al., 2018; Towne et al., 2021). Patients who live in urban areas are more likely to benefit from having access to better-resourced health care facilities with stable structures and diverse resources within their communities (Cyr et al., 2019; Yue et al., 2020). Living in urban area enables individuals to choose the most proper and convenient health care facilities, providers, and services that suit them and meets their specific needs (Loftus et al., 2018; Yue et al., 2020). In turn, individuals living in urban areas tend to experience better overall health and healthcare experiences compared to those living in rural areas (Yue et al., 2020).

SOCIAL DETERMINANTS OF HEALTH AND ACCESS TO AND TIMING OF REHABILITATION SERVICES

During *Rehabilitation 2030: a call for action* meeting, the World Health Organization (WHO) identified rehabilitation as a critical component of health in the 21st century (Larsen, 2019). In acute care, rehabilitation teams including OT and PT practitioners, analyze patients' functional and physical limitations to tailor different therapeutic sessions and improve patients' independence in various daily living activities and mobility (Jette et al., 2014). Individuals with TBI-related disabilities often require early access to rehabilitation services during their acute care stays (Andelic et al., 2012; Formisano et al., 2017; C. Y. Wang et al., 2021). Several studies have discussed the positive impacts of early rehabilitation on patients, including greater functional capabilities, higher physical performance, and enhanced quality of life (Andelic et al., 2012; Bernhardt et al., 2017; essen et al., 2021; Formisano et al., 2017; Hauer et al., 2019; C.-Y. Wang et al., 2021; Yu et al., 2020).

Individuals with TBI may experience barriers to receiving high quality health care and rehabilitation services (Bowman et al., 2022). In particular, social determinants of health (SDoH) have been identified as potential barriers to receiving high quality health care services (E. Carvalho et al., 2017; Gao et al., 2019; Zajacova & Lawrence, 2018). *Healthy People 2030* has defined SDoH as the situations in which individuals are born, reside, learn, work, play, and worship, which can influence a wide range of health and quality of life outcomes (Office of Disease Prevention and Health Promotion & Services., 2020). The WHO established the Commission on Social Determinants of Health to promote health equity and minimize health disparities among social groups within and between nations (World Health, 2017). In *Rehabilitation 2030*, there was a global movement to support fair accessibility to rehabilitation services to reduce healthcare disparities (World Health, 2017). A few studies have shown that SDoH such as individuals' income, educational levels, and residential location may negatively impact accessibility to rehabilitation services among individuals with musculoskeletal, oncologic, and other disabling conditions (Erik Carvalho et al., 2017; Zajacova & Lawrence, 2018).

Little is known regarding whether SDoH are associated with access to rehabilitation services among adults hospitalized for TBI and/or duration of first rehabilitation encounter among those who did receive services. Empirical support for the effects of SDoH on access to rehabilitation services and on duration of first rehabilitation encounter can guide efforts aimed at ensuring timely and equitable access to beneficial rehabilitation services for individuals with TBI. Obtaining a better understanding of the impacts of SDoH in TBI will help to inform policy and practice to mitigate these barriers and enhance accessibility to rehabilitation services.

REHABILITATION SERVICES UTILIZATION AND COMMUNITY DISCHARGE

A primary focus of acute care rehabilitation services is to improve patients' functional and physical performance (Ejlersen Wæhrens & Fisher, 2007). Multiple acute care studies have found that rehabilitation services are associated with improved ADL and physical performance in patients with TBI (Trevena-Peters et al., 2018; Zarshenas et al., 2019). Additionally, increased frequency of rehabilitation services utilization resulted in greater functional and physical gains at the time of discharge among patients with TBI (Kanchan et al., 2018; Zarshenas et al., 2019).

Community discharge is generally viewed as an indicator of high-quality health services provided in acute care settings (Department of Health and Human Services [HHS], 2019). Several studies have addressed the positive impacts of community discharge on patients, including higher levels of functional independence, fewer cognitive or behavioral issues, lower healthcare cost, and enhanced quality of life (Brown et al., 2020; Chevalley et al., 2022; Souesme et al., 2022; Werner et al., 2019). OT and PT services have been associated with a higher rate of community discharge (Kanchan et al., 2018; O'Brien & Zhang, 2018; Roberts et al., 2016; Souesme et al., 2022; Thorpe et al., 2018).

Little is known regarding the potential moderating effects of change in ADL/ mobility performance scores, between admission and discharge, on the association between OT/PT utilization and discharge destination (community vs. institution) among individuals with TBI. Understanding potential mechanisms by which OT and/or PT utilization and community discharge are related may inform efforts to enhance the quality or amount of acute care therapy services delivered to individuals with TBI to maximize safe community discharge.

REHABILITATION SERVICES UTILIZATION AND UNPLANNED READMISSION STATUS

Since 1960, the percentage of national healthcare expenditure in the United States as a percentage of gross domestic product (GDP) has been gradually increasing. It accounted for 5% of GDP that year, it had grown to 17.2% in 2010, and it was expected to reach 18.3% by 2021 (Statista, 2021). According to the Centers for Medicare and Medicaid Services (CMS), healthcare spending will rise by an average of 5.4% per year from 2019 to 2028. Healthcare spending is anticipated to reach over $6.2 trillion by 2028 (CMS, 2020).

Hospital readmissions are defined as unplanned inpatient admissions to the same or another acute care hospital within 30 days of discharge from a previous hospitalization (CMS, 2016). Globally, hospital readmissions are seen as a financial, social, and medical burden (Atzema et al., 2018). In the United States, hospital readmissions are common, expensive, and often avoidable among Medicare beneficiaries (MedPAC, 2018). The Medicare Payment Advisory Commission (MedPAC) projected that between 17% and 20% of Medicare beneficiaries discharged from hospitals were readmitted within 30 days (MedPAC, 2018). Around 75% of these readmissions were potentially preventable, costing Medicare $17 billion (MedPAC, 2018).

Annually, almost 1 in 5 readmissions following major surgical procedures might have been avoided, costing hospitals an estimated $300 million (Brown et al., 2021). According to the CMS, the highest readmission rates in 2016 were among Medicare adult patients aged 21-64 years and nonmaternal Medicaid patients aged 45-64 years (21.2 and 20.4 per 100 index admissions, respectively). Avoidable readmissions are caused by a variety of factors, including hospital-acquired infections, inadequate discharge or care transitions planning, medication

coordination failure, and inadequate communication among healthcare teams, patients, and caregivers (Qiu et al., 2022).

Readmission is a typical issue for those who have chronic illnesses or injuries, and it is associated with higher healthcare expenses and lower quality of care (Jencks et al., 2009). Readmission rates after TBI contribute considerably to these costs, making lowering readmission rates a universal goal (Canner et al., 2016). According to the department of Health and Human Services' (HHS) 2018 public access report, readmission for TBI occurred at a rate of 27.8% in the first year following discharge, with little change in subsequent years, averaging 22-23.4% (Zatzick et al., 2017). Although some readmissions are scheduled for elective treatments like cranioplasty, orthopedic surgery, or other reconstructive surgeries, others are unplanned and may disrupt the intended course of acute inpatient rehabilitation while also limiting neurological and functional progress (Hammond et al., 2015; Hoffman et al., 2020).

Several diagnoses are associated with higher readmissions among individuals with TBI including neurosurgical issues such as craniotomy, seizure, and intracranial hemorrhage as well as infections (Brito et al., 2019; Hammond et al., 2015; Hoffman et al., 2020; Nakase-Richardson et al., 2013; Tran et al., 2017). Other studies indicate that psychosocial conditions such as dementia, depression, anxiety, and alcohol abuse are also associated with readmission in TBI survivors (Canner et al., 2016; Gardner et al., 2018; Ho et al., 2019; Li et al., 2018; Zatzick et al., 2017). A few studies reported that Congestive Heart Failure, pneumonia, and chronic obstructive pulmonary diseases were also among the primary diagnoses of readmission among patients with TBI (Brown et al., 2021; Saverino et al., 2016).

Several programs and measures have been established to encourage hospitals to improve communication and care coordination in order to better engage patients and caregivers in

discharge plans and, in turn, reduce avoidable readmissions (CMS, 2016 ; International, 2015). Four of those programs are briefly described below.

- The Centers for Medicare & Medicaid Services (CMS) established the Hospital Readmissions Reduction Program (HRRP) in 2012 (CMS, 2016). The program's goal is to reduce unnecessary readmissions among Medicare beneficiaries by penalizing hospitals that have higher than predicted 30-day all-cause readmission rates for specified diseases or procedures. The penalty amount fluctuates between 0.3% and 3% (CMS, 2016). Six readmission measures are covered by the HRRP, covering four medical disorders (Acute Myocardial Infarction, Chronic Obstructive Pulmonary Disease, Heart Failure, and Pneumonia); and two surgical procedures (Coronary Artery Bypass Graft, and elective primary Total Hip Arthroplasty and/or Total Knee Arthroplasty) (McIlvennan et al., 2015).
- The potentially preventable 30-day post-discharge readmission measures for Skilled Nursing Facility (SNF), Inpatient Rehabilitation Facility (IRF), Long-Term Care Hospital (LTCH), and Home Health (HH) assess readmissions during a 30-day period after discharge from the post-acute care provider was implemented in 2019 (CMS, 2019). These measures, like others, seek to enhance healthcare quality, improve population health in the United States, and reduce health-care expenditures (CMS, 2019). Condition-specific, procedure-specific, and hospital-wide indicators are among the possibly preventable 30-day post-discharge readmission measures (CMS, 2019). These metrics are associated with conditions and procedures such as Myocardial Infarction, Chronic Obstructive Pulmonary Disease, Heart Failure, and Pneumonia, Coronary Artery Bypass Graft, and elective primary Total Hip Arthroplasty and/or Total Knee Arthroplasty, and hospital-wide all cause readmission (CMS, 2019).

- The CMS published the potentially avoidable within-stay measure for IRFs in 2017, which evaluates readmissions that occur while the patient is still receiving services at an IRF (CMS, 2019). Temporary transfers (interruptions in rehabilitation programs) and discharges to acute care are examples of "within stay" readmissions (Middleton et al., 2017). This within-stay measure focuses on potentially avoidable medical diagnoses and aims to improve care coordination and communication between the IRF and acute care facilities to prevent unnecessary readmissions (Middleton et al., 2017). A list of potentially preventable diagnoses has been developed for the within stay readmission measure comprising Asthma, chronic obstructive pulmonary disease, congestive heart failure, diabetes mellitus, high blood pressure, influenza, pneumonia, infections, acute delirium, arrhythmia, anemia, pressure ulcers, deep vein thrombosis, head injury, and upper and lower extremities fractures (International, 2015). These diagnoses are divided into five categories including 1) insufficient chronic condition management, 2) poor infections management, 3) improper management of unplanned events, 4) inadequate prophylaxis, and 5) inadequate injury prevention (International, 2015).
- In 2019, the CMS published potentially preventable hospital readmission measure for SNF, IRF, LTCH, and HH (CMS, 2019). These potentially preventable hospital readmission measures are designed to assess the readmission rates of patients who are readmitted to the hospital due to unplanned and potentially preventable reasons, which align with the requirements of the Improving Medicare Post-Acute Care Transformation (IMPACT) Act and the CMS Meaningful Measures Initiative (CMS, 2019). These measures aimed to address high-priority areas for quality of care and outcomes for patients, families, and providers (CMS, 2019).

Numerous studies have demonstrated that lowering readmission rates leads to better outcomes for the general population, including decreased financial burdens for patients, caregivers, providers, and payers (Hoffman et al., 2020; Middleton, Graham, et al., 2018; Mitsutake et al., 2020). However, there is limited knowledge about the relationship between patients' functional/physical status at discharge and 90-day unplanned readmission status in adults with TBI. By examining the impact patients' functional/physical status at discharge on 90-day unplanned readmission status in adults with TBI of individuals with TBI, therapists can identify patients at risk and provide the necessary resources, support, and follow-up programs to inform discharge planning, care transitions, and prevention efforts.

RELATION TO OCCUPATION SCIENCE (OS) & REHABILITATION SCIENCE (RS)

Relation to Occupation Science

My dissertation project is directly relevant to OS. First, (Molineux) (2010) described OS as "an interdisciplinary field of study concerned with understanding human occupation in context and the relationship between occupation and health viewed broadly to include optimal well-being" (p.370). My research focuses on factors that influence obtaining timely access to rehabilitation services, safely discharging to the community, and avoiding unplanned readmission among patients with TBI. Prior studies investigated the positive impacts of these factors among patients with other conditions, including better outcomes, improved function, and enhanced quality of life (Andelic et al., 2012; Bernhardt et al., 2017; Middleton, Downer, et al., 2018; C. Y. Wang et al., 2021).

Second, focusing on early access to rehabilitation services is related to the concept of occupational justice (Dickie, 2006; Hocking, 2017; Townsend & Wilcock, 2004; Wagman et al., 2014). Occupational justice is defined as "equitable or fair opportunities and resources to do, be,

belong and become what people have the potential to be and the absence of avoidable harm" (Townsend & Wilcock, 2004)p. 414). My research findings will provide knowledge for practitioners about the impact of SDoH on early access to services. This increased understanding will enable therapists to consider these factors when working with TBI patients and provide needed resources to support their needs and self-advocacy. This will facilitate service accessibility, and therefore allow individuals with TBI to have meaningful engagement in rehabilitation activity during their acute care stay, improving their overall well-being (Béavogui et al., 2015; Mehmood et al., 2021b).

Third, my research around community discharge and 90-day readmission status reflects the relationship between occupation and meaning. (Hasselkus, 2011a) presented the environment as a source of meaning in occupation in terms of place and space. As experiences and memories are created in a certain space, that space becomes a place that holds values and emotions. By discharging to the community and avoiding 90-day readmission, individuals with TBI will remain in the places that they value and bring them positive emotions and experiences, enabling them to be and become who they want and live in a way that meets their needs (Brown et al., 2020; Hasselkus, 2011b).

Lastly, (Dickie, 2006) introduced the notion of transactionalism, which describes occupation as a result of not only personal experiences but also other social, physical, environmental, and cultural contexts. My research takes a transactive approach by considering the wider contexts influencing accessibility and outcomes in rehabilitation. Specifically, this research looks into social (e.g., presence of significant other), environmental (e.g., residence location), and cultural contexts to understand how they impact occupational engagement (Dickie, 2006).

Relation to Rehabilitation Science

My research is also related to RS in several ways. First, studying factors impacting individuals with TBI access to rehabilitation services and outcomes aligns with the Institute of Medicine model (IOM) of disability ("Disability in America," 1991). In the enabling-disabling model, disability is viewed as a result of the interaction between the person and environmental factors such as physical, social, and psychological (Medicine et al., 1997). In my studies, I will examine factors such as age, sex, TBI severity level, health insurance types, and rehabilitation utilization. Thus, this research will not only look at the personal factors, but also the broader structural and environmental elements that enable or disable the person's functioning and participation.

Second, investigating factors affecting early service accessibility is consistent with the vision of Brain Injury Association of America (BIAA) (Gordon et al., 2006). BIAA was founded in 1979 to advocate for more research and health care accessibility for people with TBI (Gordon et al., 2006). This project will shed light on the social and environmental challenges that this population faces, and the barriers that prevent them from gaining early access to necessary services. The findings will help inform policy and practice to mitigate these barriers and increase accessibility to rehabilitation services. This also will be informative for therapists who work with this population in terms of providing needed resources and support that enable them to advocate for receiving more timely and better quality care.

Third, my research aligns with elements within the International Classification of Functioning, Disability, and Health (ICF) model (World Health Organization, 2001). The ICF model focuses on health and functioning rather than disability and presents an inclusive view of disability that takes into account the biological, personal, and social contexts (World Health

Organization, 2001). At the body structure and function level, my research will examine changes in self-care and mobility domine scores between admission and discharge and how they affect post-discharge outcomes. Studying the impact of change in self-care and mobility scores on community discharge and avoiding 90-day readmission will improve understanding of how body structures and functions impact health outcomes (Skidmore, 2006). In terms of environmental and personal factors, this research will closely look at person characteristics and social determinants of health that facilitate or hinder function and participation among TBI patients. For activity and participation, experiencing early access to rehabilitation services, supportive environment, and sense of mastery and challenge will enhance activity engagement and meaningful participation among patients in acute care (Law, 2002; World Health Organization, 2001).

Fourth, the ICF and ICD established a common language among disciplines and unified rehabilitation related terms and concepts which facilitate exchange of knowledge among healthcare professionals (e.g., OT and PT) (Stucki, 2005; World Health Organization, 2001). Similar taxonomies will enable practitioners and researchers from different disciplines to collaborate and provide effective interdisciplinary services and research. Using large datasets in my research with ICF language will allow me to communicate with other practitioners and researchers, resulting in a better understanding and interpretation of research findings.

OVERALL PURPOSE AND SIGNIFICANCE

Our understanding of the influence of SDoH on access to and timing of rehabilitation services; the effect of functional and physical gains on the relationship between OT/PT utilization and discharge disposition; and the relationship between acute care Activity Measure for Post-Acute Care (AM-PAC) “6 clicks” score at discharge and 90-day readmission among

patients with TBI are still limited. Therefore, more research is required to provide comprehensive understanding of the barriers, predictors, and facilitators of equitable access to and timing of rehabilitation services, community discharge, and potentially preventable 90-day post-discharge hospital readmission among individuals with TBI. The findings of these dissertation studies will be used to inform the following: study one will provide empirical support for equitable access to timely of rehabilitation services, study two will provide valuable information about proper safe discharge planning to optimize rehabilitation outcomes, and study three will provide information on reducing avoidable readmissions among people with TBI.

CONCLUSION

Overall, I believe that this literature review will be useful in guiding the subsequent sections of my dissertation. The expected outcome of this dissertation is a comprehensive understanding of the barriers, predictors, and facilitators of equitable access to rehabilitation services, community discharge, and potentially preventable 90-day post-discharge hospital readmission among individuals with TBI. The results will have an important impact because they will provide empirical support for timely and fair access to rehabilitation services, and proper safe discharge planning to optimize rehabilitation outcomes, and reduce avoidable readmission among individuals with TBI.

CHAPTER TWO: THE ASSOCIATION BETWEEN SOCIAL DETERMINANTS OF HEALTH AND BOTH ACCESS TO AND TIMING OF REHABILITATION SERVICES AMONG ADULTS HOSPITALIZED WITH TRAUMATIC BRAIN INJURY

OVERVEIW

Objective: To examine whether social determinants of health (SDoH) are associated with 1) access to occupational therapy (OT), and physical therapy (PT) services among adults hospitalized for traumatic brain injury (TBI) and/or 2) duration to first rehabilitation (OT, & PT) encounter among patients with TBI who received therapy services.

Setting: 14 acute care hospitals in the state of Colorado.

Participants: 5,542 adults hospitalized with TBI between June 2018 and April 2021.

Design: In a secondary analysis of de-identified electronic health record (EHR) data, we performed multivariable logistic and Cox regression analyses to calculate odds ratios for the likelihood of receiving services and hazards ratios for the duration to initiation of services among those who received them.

Main Measures: Community-level SDoH (e.g., education, income, and rurality), receipt of rehabilitation services, utilization of rehabilitation services, and time of rehabilitation services.

Results: Multivariable logistic and Cox regressions revealed positive associations between patients' age and their access to and timing of OT and PT services in acute care. Patients with no significant other were less likely to receive OT (OR= 0.82, 95% CI [0.68, 0.99]) service. Black individuals experienced a longer wait time (in days) to receive OT (HR= 0.88, 95% CI [0.77, 0.99]) service. Patients with private insurance had greater odds of receiving OT (OR= 1.35, 95% CI [1.08, 1.70]) and PT (OR=1.47, 95% CI [1.16, 1.87]) services. Patients with Medicaid

insurance experienced a longer wait time to receive OT (HR=0.90, 95% CI [0.83-0.98]) and PT (HR=0.91, 95% CI [0.83-0.98]) services. Patients with mild or moderate TBI and lower comorbidity burdens had greater odds of receiving both OT (Mild TBI OR=2.97, 95% CI [1.71, 5.14]; Moderate TBI OR=3.39, 95% CI [2.01, 5.70]; Comorbidity burden OR = 0.95, 95% CI [0.91, 0.99]) and PT (Mild TBI OR=3.17, 95% CI [1.82, 5.54]; Moderate TBI OR = 3.68, 95% CI [2.17, 6.24]; Comorbidity burden OR = 0.95, 95% CI [0.89, 0.98]). Patients with severe TBI experienced a longer wait time to receive OT (HR=0.80, 95% CI [0.65-0.98]) service. Patients with a longer length of stay (LOS) were more likely to access OT (OR= 1.23, 95% CI [1.19, 1.27]) and PT (OR=1.23, 95% CI [1.18, 1.27]) services. However, a longer LOS in acute care was associated with a longer wait time to receive OT (HR=0.99, 95% CI [0.99-1.00]) and PT (HR=0.94, 95% CI [0.93-0.94]) services. Community-level education attainment indicators, income, and rurality did not show significant associations with access or timing of acute rehabilitation services.

Conclusion: Further investigation is needed to ascertain whether the community-level SDoH variables, based on the first three digits of zip codes, adequately capture individual experiences and their impact on healthcare, or if community-level education, income, and rurality genuinely do not affect access to and timing of therapy services for hospitalized patients with TBI. Notably, several individual-level variables, including age, race/ethnicity, the presence of significant others, insurance type, length of stay (LOS), comorbidity burden, and TBI severity, displayed statistically significant strong associations with both services access and timing. These findings have implications for therapists working in acute care and for shaping better policies to facilitate better access to rehabilitation services.

The Association Between Social Determinants of Health and Both Access to and Timing of Rehabilitation Services Among Adults Hospitalized with Traumatic Brain Injury

Introduction

Traumatic brain injury (TBI) can result in serious health and functional consequences requiring hospitalization (i.e., acute care) and post-acute care. There are approximately 2.5 million TBI-related emergency department (ED) visits, 288,000 TBI-related hospitalizations, and 61,000 TBI-related deaths in the United States annually (Centers for Disease Control and Prevention, 2019). TBI is associated with limitations in basic functional (i.e., bathing, dressing, eating, or toileting) and mobility activities (Klima et al., 2019; J. Lo et al., 2021; Whiteneck et al., 2016).

Individuals who are hospitalized with TBI should receive equitable access to multidisciplinary care, including rehabilitation services (occupational therapy [OT], and physical therapy [PT]) to address potential self-care issues, physical limitations, and cognitive deficits (National Academies of Sciences & Medicine, 2022). Early onset of acute care rehabilitation services can have positive short and long-term benefits for patients, including accelerated recovery rate, improved function, increased mobility, and enhanced quality of life (Andelic et al., 2012; Bernhardt et al., 2017; Naess et al., 2020; C. Y. Wang et al., 2021).

Unfortunately, some individuals with TBI experience barriers to timely and equitable access to rehabilitation services in acute care (Bowman et al., 2022). In particular, social determinants of health (SDoH) have been implicated as potential barriers to accessing needed health care (E. Carvalho et al., 2017; Gao et al., 2019; Zajacova & Lawrence, 2018), and may

impede patients with TBI from receiving prompt acute care rehabilitation. Healthy People 2030 has defined SDoH as the situations in which individuals are born, reside, learn, work, play, and worship, which can influence a wide range of health and quality of life outcomes, including access to health care (Office of Disease Prevention and Health Promotion & Services., 2020). A few studies have found that SDoH, including individuals' median income, educational levels, and residence location may have a detrimental impact on accessibility to rehabilitation services among individuals with musculoskeletal, oncologic, and other disabling conditions (E. Carvalho et al., 2017; Gao et al., 2019; Zajacova & Lawrence, 2018).

However, limited knowledge exists regarding the influence of SDoH on the access and timing of acute care rehabilitation services among patients with TBI. Empirical evidence on the effects of SDoH on access and timing of rehabilitation services can contribute to the Centers for Medicare and Medicaid Services (CMS) framework for health equity 2022 – 2032 (CMS, 2022). This study will address the following key priorities outlined by the CMS framework: 1) increasing standardized data collection, reporting, and analysis, 2) evaluating the causes of disparities and addressing inequities within CMS programs in policies and operation, 3) enhancing healthcare organizations and workers to diminish health and healthcare disparities, and 4) improving accessibility to healthcare services and coverage in all aspects (CMS, 2022). This study will also be informative for therapists who work with this population in terms of providing needed resources and support that enable them to advocate for receiving timely and higher quality care.

The purpose of this study was to investigate whether SDoH impact access to and timing of rehabilitation services in acute care. We hypothesized (1) patients with social risk factors (e.g., lower median income and education level) are less likely to receive rehabilitation services; and

(2) patients with social risk factors who receive rehabilitation services would have a longer time in the hospital before receiving rehabilitation services after adjusting for patient-level risk factors.

METHODS

Participants and procedure

This was a retrospective cross-sectional study of de-identified electronic health record (EHR) data for patients admitted to 14 trauma centers, levels I to IV, within a single large health system in the state of Colorado. The initial sample included 401,350 patients admitted and discharged between June 2018 and April 2021. In this study, patients were included if they were an adult (aged ≥ 18 years), admitted to the hospital with a TBI diagnosis based on ICD-10 codes for admission (See appendix A), survived hospitalization, and had complete data for the variables of interest. The data were validated, de-identified, organized, and supported by the Health Data Compass Data Warehouse project (healthdatacompass.org). After applying the inclusion criteria, the final sample consisted of 5,542 adults (Figure 1). Although we excluded subjects with missing data, close examination of patients with missing data revealed no systematic differences in the independent or dependent variables compared to patients without missing data. A signed data-use agreement was in-place, and the study was approved by Colorado State University Institutional Review Board. The *Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)* reporting guidelines were applied to this study (von Elm et al., 2014). See appendix B for more information about *STROBE* statements.

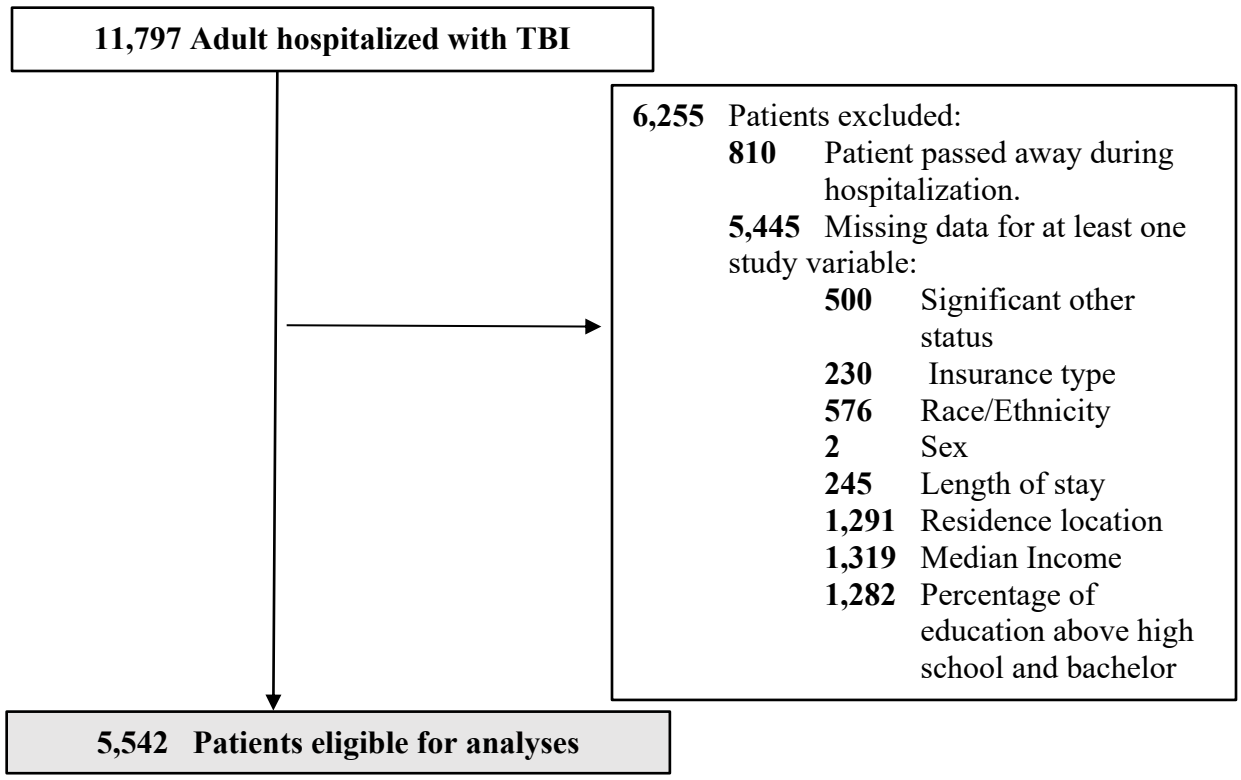

Figure 1. Cohort Selection Diagram

Measures

Receipt of rehabilitation services for hypothesis (1)

Receipt of OT and PT services was defined by determining whether the patient had been billed for any OT or PT evaluation and/or treatment during the acute care stay (yes/no).

Utilization of rehabilitation services for hypothesis (2)

An indicator was generated for patients who did not receive any OT or PT services during their acute care stay (i.e., censored).

Timing of rehabilitation services for hypothesis (2)

For patients who received rehabilitation services (i.e., OT or PT), time of rehabilitations services was defined as the duration (in days) between hospital admission and the initiation of

these services. For patients who did not receive these services, this variable was defined as the length of stay (in days) between hospital admission and discharge.

Independent Variables

Community-level social determinants of health (SDoH)

The following community-level SDoH were measured based on patients with TBI first three-digit zip codes: 1) Median income; 2) percentage of patients with above high school attainment; 3) percentage of patients with above bachelors' education attainment; and 4) rurality. Median income was defined as a continuous variable and measured in US dollars ($). The percentage of above high school and bachelors' education attainment were defined as continuous variables representing the percentage of individuals within the community who had attained above high school or bachelor's level education. Rurality was measured by categorizing patients' residential location into "Urban" vs. "Rural" using Zip Code Tabulation Areas (ZCTAs).

Covariates

We included person-level factors such as age (years); sex (female; male); race/ethnicity (White Black; Hispanic; Multiple race; and Other [e.g., Asian; American Indian; Alaska native; native Hawaiian; and Pacific Islander), presence/absence of a significant other, insurance type (e.g., Medicare; Medicaid; VA; Others; and Private), length of stay (days), comorbidity burden (using Functionally relevant TBI Comorbidity Index [Fx-TBI-CI] (Kumar et al., 2022)), and TBI severity (e.g., Mild; Moderate; and Severe (Defense and Veterans Brain Injury Center, 2015)) as covariates. The Fx-TBI-CI is a method used to categorize patients' with TBI comorbidities based on the International Classification of Diseases (ICD-10) diagnosis codes obtained from hospital administrative data (Kumar et al., 2022). The Fx-TBI-CI was calibrated based on the function of individuals with TBI receiving inpatient care (Kumar et al., 2022). We constructed a weighted

summary index according to Kumar et al. to evaluate comorbidity burden (2022). We used ICD-10 diagnosis codes obtained from the Defense and Veterans Brain Injury Center (DVBIC) to classify TBI severity: mild, moderate, and severe (Defense and Veterans Brain Injury Center, 2015).

Data analysis

Descriptive statistics (e.g., means, standard deviations, percentages) were computed for the entire sample and stratified by received rehabilitation services (yes/no) and duration to first rehabilitation encounter for both OT and PT. For the unadjusted (bivariate) analyses, we used Chi-square, independent t-tests, ANOVAs, and Pearson Correlations, as appropriate. Specifically, Chi-square and ANOVA analyses were conducted to assess the association between dichotomous and categorical variables (i.e., three or more levels), respectively, and the dependent variables (e.g., receipt of rehabilitation services [yes/no]). Independent t-tests were utilized to examine the association between all continuous variables and the dependent variables (e.g., receipt of rehabilitation services [yes/no]). Additionally, Pearson Correlations were conducted to assess whether continuous variables were correlated with the duration to the onset of both OT and PT services as the dependent variables. Logistic regression analyses were performed with receipt of rehabilitation services (e.g., OT and PT) status as the dependent variables and community-level SDoH (e.g., education, income, and rurality) as the main predictors of interest. Cox regression analyses (i.e., time-to-event analyses) were used to estimate hazard ratios for the timing of first rehabilitation services (e.g., OT and PT) encounter (in days) among those who received these services (i.e., early/shorter wait, or delay/longer wait) as the dependent variables and community-level SDoH (e.g., education, income, and rurality) as the main predictors of interest. Estimates (e.g., odds ratios, hazard ratios, confidence intervals) were

adjusted for age, sex, race/ethnicity, presence/absence of a significant other, insurance type, length of stay, comorbidity burden, and TBI severity levels. Statistical significance was evaluated at $\alpha = .05$ for all parameter estimates. All analyses were performed using R (Version 4.3.1) (R Core Team, 2023).

RESULTS

Patient Demographics & Utilization of Rehabilitation Services

Most of the 5,542 patients received OT (88%) and PT (89%) services (Table 1). There were no statistically significant differences between those receiving and not receiving OT or PT services on any of the community-level SDoH variables (*p*-values= 0.056 - 0.954). Mean community-level income was $63,000. Community high school and bachelor's degree completion were nearly 91% and 36%, respectively. More than 90% of the patients lived in urban communities. Associations between individual sociodemographic characteristics and service utilization were remarkably similar for OT and PT. Mean age of the sample was approximately 55 years. Those who received either OT or PT services were 10 years older, on average, than those who did not receive therapy. Nearly two-thirds of the sample was male (64.2%); however, females were slightly more likely to receive both OT (89.6%) and PT (90.9%) services. Similarly, those with a significant other were slightly more likely to receive OT (90.0%) and PT (90.9%) compared to those without a significant other (85.9% and 87.7%, respectively). Medicare was the most common insurance coverage (39.1%) and patients with Medicare were most likely to receive both OT (92.5%) and PT (93.4%) services. More than 80% of the sample experienced a moderate TBI; patients with a moderate TBI had the highest utilization rates for both OT (88.4%) and PT (89.9%) services. Overall mean length of stay was 5.8 days and those receiving either OT or PT services stayed three days longer, on average, than

those not receiving therapy. The mean weighted FX-TBI-CI score of 1 was notably low, which indicates that most of the patients have lower associated comorbidity conditions. Race/ethnicity was associated with receiving OT (*p*-value= 0.001) and PT (*p*-value= 0.01). See Table 1.

Table 1 Sample characteristics with descriptive summaries of OT and PT service delivery

		OT Services			PT Services		
	Total	No	Yes	*p*-value	No	Yes	*p*-value
Total	5542	685 (12.4%)	4857 (87.6%)		606 (10.9%)	4936 (89.1%)	
Community level SDoH variables							
Income, mean (SD)*	63.2 (20.4)	62.0 (20.0)	63.3 (20.4)	.240	61.9 (19.4)	63.3 (20.5)	.056
High School, mean % (SD)	90.9 (7.4)	90.5 (7.6)	90.9 (7.4)	.248	90.8 (7.3)	90.9 (7.4)	.657
Bachelor's, mean % (SD)	35.7 (15.9)	35.3 (16.0)	35.7 (15.9)	.860	35.4 (15.8)	35.7 (15.9)	.810
Community Density				.642			.954
Urban	5063	629 (12.4%)	4434 (87.6%)		554 (10.9%)	4509 (89.1%)	
Rural	479	56 (11.7%)	423 (88.3%)		52 (10.9%)	427 (89.1%)	
Age in years, mean (*SD*)	54.8 (20.1)	46.0 (18.3)	56.0 (20.1)	**<.001**	45.4 (18.2)	55.9 (20.1)	**<.001**
Sex				**.001**			**<.001**
Female	1986	207 (10.4%)	1779 (89.6%)		180 (9.1%)	1806 (90.9%)	
Male	3556	478 (13.4%)	3078 (86.6%)		426 (12.0%)	3130 (88.0%)	
Significant other				**<.001**			**<.001**
Yes	2328	233 (10.0%)	2095 (90.0%)		211 (9.1%)	2117 (90.9%)	
No	3214	452 (14.1%)	2762 (85.9%)		395 (12.3%)	2819 (87.7%)	
Race/Ethnicity				**.001**			**.007**
White	4010	461 (11.5%)	3549 (88.5%)		409 (10.2%)	3601 (89.8%)	
Black	341	56 (16.4%)	285 (83.6%)		45 (13.2%)	296 (86.8%)	
Hispanic	877	132 (15.1%)	745 (84.9%)		120 (13.7%)	757 (86.3%)	
Multiple race	103	17 (16.5%)	86 (83.5%)		15 (14.6%)	88 (85.4%)	
Other	211	19 (9.0%)	192 (91.0%)		17 (8.1%)	194 (91.9%)	
Insurance type				**<.001**			**<.001**

Medicare	2165	163 (7.5%)	2002 (92.5%)		142 (6.6%)	2023 (93.4%)	
Medicaid	1426	256 (18.0%)	1170 (82.0%)		231 (16.2%)	1195 (83.8%)	
VA	154	30 (19.5%)	124 (80.5%)		26 (16.9%)	128 (83.1%)	
Other	389	58 (14.9%)	331 (85.1%)		55 (14.1%)	334 (85.9%)	
Private	1408	178 (12.6%)	1230 (87.4%)		152 (10.8%)	1256 (89.2%)	
TBI Severity				**<.001**			**<.001**
Mild	825	130 (15.8%)	695 (84.2%)		118 (14.3%)	707 (85.7%)	
Moderate	4585	531 (11.6%)	4054 (88.4%)		465 (10.1%)	4120 (89.9%)	
Severe	132	24 (18.2%)	108 (81.8%)		23 (17.4%)	109 (82.6%)	
Length of stay in day, mean (SD)	5.8 (5.6)	3.2 (3.6)	6.2 (5.8)	**<.001**	3.2 (3.7)	6.1 (5.7)	**<.001**
FX-TBI-CI, mean (*SD*)	1.0 (2.4)	0.7 (1.9)	1.0 (2.5)	**<.001**	0.7 (2.0)	1.0 (2.4)	**.001**

Note: SD=standard deviation; SDoH= Social Determinants of Health; FX-TBI-CI = functionally relevant TBI comorbidity index; * *p*-value for the bivariate analyses: chi-square, t-test; *Income amounts are in US thousands of dollars.

Among those who received rehabilitation services during their acute care stay, none of the SDoH variables were significantly correlated with the timing of initial therapy evaluation/ treatment (Table 2). Age was negatively and significantly correlated with the timing of initial OT and PT services (r= -0.130; r= -0.129; p< 0.001, respectively). Length of stay was positively and statistically significantly correlated with the timing of initial OT and PT services OT and PT services (r= 0.347; r= 0.337; p< 0.001, respectively). The comorbidity burden was also positively and significantly correlated with the timing of initial OT and PT services (r= 0.116; r= 0.119; p< 0.001, respectively). There was a statistically significant difference between females and males concerning the timing of initial OT (t(4885)=-3.77, p< 0.001) and PT services (t(4965)=-3.60, p< 0.001). Meaning that females experienced shorter wait time

(in days) to receive rehabilitation services compared to males. There was a statistically significant difference between patients with and without significant others regarding the timing of initial OT and PT services ($t(4885)=-2.25$, $p= 0.019$; $t(4965)=-2.46$, $p= 0.011$, respectively). Indicating that patients with significant other experienced shorter wait time (in days) to receive rehabilitation services compared to those without significant other. There was a statistically significant difference between TBI severity groups regarding the timing of initial OT ($F(18, 4868)=3.18$, $p< 0.001$), and PT services ($F(18, 4948)=3.26$, $p< 0.001$). However, there were not statistically

significant differences between race/ethnicity or insurance type groups in relation to timing of initial OT and PT services (p-values= 0.981).

Table 2 Sample characteristics with descriptive summaries of OT and PT duration to onset of therapy

	N*	Days to OT	*p*-value	N*	Days to PT	*p*-value
Total	4857	0.71 (1.57)		4936	0.69 (1.55)	
Community level SDoH variables						
Income, correlation		-0.028	.051		-0.025	.081
High School, correlation		0.001	.954		0.007	.613
Bachelor's, correlation		-0.021	.147		-0.017	.239
Community Density			.103			.226
Urban	4434	0.72 (1.59)		4509	0.69 (1.57)	
Rural	423	0.60 (1.39)		427	0.61 (1.41)	
Age, correlation		-0.130	**<.001**		-0.129	**<.001**
Sex			**<.001**			**<.001**
Female	1779	0.60 (1.35)		1806	0.58 (1.33)	
Male	3078	0.77 (1.69)		3130	0.75 (1.67)	
Significant other			**.019**			**.011**
Yes	2095	0.65 (1.53)		2117	0.62 (1.51)	
No	2762	0.75 (1.60)		2819	0.73 (1.59)	
Race/Ethnicity			.981			.981
White	3549	0.69 (1.52)		3601	0.67 (1.51)	
Black	285	1.09 (2.41)		296	1.00 (2.33)	
Hispanic	745	0.68 (1.47)		757	0.65 (1.41)	
Multiple race	86	0.77 (1.63)		88	0.78 (1.83)	
Other	192	0.63 (1.20)		194	0.62 (1.20)	
Insurance type			.095			.099
Medicare	2002	0.53 (1.16)		2023	0.51 (1.11)	
Medicaid	1170	0.96 (2.04)		1195	0.93 (1.99)	
VA	124	0.80 (1.48)		128	0.77 (1.46)	
Other	331	0.61 (1.25)		334	0.59 (1.25)	
Private	1230	0.77 (1.70)		1256	0.76 (1.72)	
TBI Severity			**<.001**			**<.001**
Mild	695	0.67 (1.22)		707	0.62 (1.17)	
Moderate	4054	0.68 (1.52)		4120	0.66 (1.50)	
Severe	108	1.98 (3.78)		109	1.96 (3.76)	
Length of stay, correlation		0.347	**<.001**		0.337	**<.001**
FX-TBI-CI, correlation		0.116	**<.001**		0.119	**<.001**

Note: SD=standard deviation; SDoH= Social Determinants of Health; FX-TBI-CI = functionally relevant TBI comorbidity index; *p*-value for: t-test, ANOVA, and Pearson Correlation; *only include the subset of patients who received the OT and PT services n = 4857 and n = 4936, respectively.

Receipt of Rehabilitation Services

There was not sufficient evidence to suggest that the community-level SDoH variables (i.e., income, education attainment, and rurality) were good predictors of receipt of OT and PT services (*p*-values= 0.09 – 0.95) (Table 3). Age demonstrated statistically significant positive associations with the log odds of receipt of both OT and PT ($\hat{\beta}$= 0.02; SE= 0.003; *p*-value <0.001). The presence of a significant other was significantly and positively associated with the log odds of the receipt of OT service ($\hat{\beta}$= 0.19; SE= 0.10; *p*-value=0.04). Compared to those with private insurance, those with Medicaid insurance were significantly and negatively associated with log odds of the receipt of OT and PT services ($\hat{\beta}$= -0.30; SE= 0.12; *p*-value =0.01; and $\hat{\beta}$= -0.38; SE= 0.12; *p*-value<0.001, respectively). In comparison with mild TBI, severe TBI was negatively associated with log odds of the receipt of OT and PT services ($\hat{\beta}$= -1.09; SE= 0.28, and $\hat{\beta}$= -1.15; SE= 0.28; *p*-value<0.001, respectively). Comorbidity burden score was significantly and negatively associated with log odds of the receipt of OT and PT services ($\hat{\beta}$= -0.05; SE= 0.02; *p*-value=0.02; and $\hat{\beta}$= -0.07; SE= 0.02; p <0.001, respectively). Longer length of stay was positively associated with log odds of the receipt of OT service and PT services ($\hat{\beta}$= 0.21; SE= 0.02; and $\hat{\beta}$= 0.20; SE= 0.02; *p*-value<0.001, respectively). There was not sufficient evidence to suggest that the other covariates (i.e., sex, and race/ethnicity) were significantly associated with receipt of OT and PT services (*p*-value range = 0.23 – 0.76). Table 3 presents the coefficient estimates from the logistic regression analysis.

Table 3. Regression coefficients results of logistic regression analyses for receipt of OT and PT services.

	Occupational Therapy (OT)			Physical Therapy (PT)		
	Beta coefficients	Standard error (SE)	*P*-value	Beta coefficients	Standard error (SE)	*P*-value
Intercept	-0.79	0.75	0.29	0.21	0.80	0.79
Community level SDoH variables						
Income	0.00	0.00	0.79	0.00	0.00	0.45
High School	0.01	0.01	0.15	0.00	0.01	0.89
Bachelors	-0.01	0.00	0.09	-0.01	0.00	0.19
Residence (ref. = Rural)						
Urban	-0.01	0.16	0.95	0.05	0.17	0.76
Age (years)	0.02	0.00	**<0.001**	0.02	0.00	**<0.001**
Sex (ref. = Female)	-0.10	0.09	0.27	-0.12	0.10	0.23
Significant other (ref.= No)	0.19	0.10	**0.04**	0.11	0.10	0.26
Race/Ethnicity (ref. = White)						
Black	-0.19	0.17	0.26	-0.09	0.18	0.63
Hispanic	-0.06	0.12	0.63	-0.09	0.12	0.45
Multiple race	-0.12	0.29	0.69	-0.09	0.31	0.76
Other	0.24	0.25	0.35	0.22	0.27	0.42
Insurance Type (ref. = Private)						
Medicare	0.10	0.15	0.50	0.00	0.16	1.00
Medicaid	-0.30	0.12	**0.01**	-0.38	0.12	**<0.001**
VA	-0.32	0.23	0.17	-0.29	0.25	0.24
Other	0.05	0.17	0.79	-0.09	0.18	0.61
TBI severity (ref. = Mild)						
Moderate	0.13	0.11	0.24	0.15	0.12	0.20
Severe	-1.09	0.28	**<0.001**	-1.15	0.28	**<0.001**
Length of stay (days)	0.21	0.02	**<0.001**	0.20	0.02	**<0.001**
FX-TBI-CI	-0.05	0.02	**0.02**	-0.07	0.02	**<0.001**

Note: SDoH= Social Determinants of Health; Ref. = reference category; VA= Veterans Affairs; FX-TBI-CI = functionally relevant TBI comorbidity index; Bold value= Significant *p*-value <0.05.

Probabilities of receiving rehabilitation services for each significant other status, insurance type, and TBI severity are provided in (Table 4). The estimated probability of receiving OT service was highest for those individuals with significant others (0.89). Among the insurance type groups, those with private, Medicare, and other types of insurance had the highest probability (0.89) of receiving OT services, followed by those with Medicaid and VA, who had an (0.85) probability of receiving OT service. Similarly, for PT service, those with private and Medicare insurance had the highest estimated probability at (0.90), followed by the 'other' category, VA, and then Medicaid. Regarding TBI severity, patients with moderate TBI had the highest probability (0.92) for receiving OT and (0.93) for PT services, while those with severe TBI had lowest probability (0.76) for OT and (0.77) for PT services.

Table 4. Results of the estimated probability of receiving rehabilitation services of the significant groups from logistic regression analyses.

	Occupational Therapy (OT)				Physical Therapy (PT)			
	Probabilities	Standard error (SE)	Asymp LCL	Asymp UCL	Probabilities	Standard error (SE)	Asymp LCL	Asymp UCL
Significant other								
No	0.86	0.02	0.82	0.90	--	--	--	--
Yes	0.89	0.02	0.85	0.91	--	--	--	--
Insurance Type								
Medicare	0.89	0.02	0.86	0.92	0.90	0.02	0.87	0.93
Medicaid	0.85	0.02	0.81	0.89	0.86	0.02	0.82	0.90
VA	0.85	0.03	0.77	0.90	0.87	0.03	0.80	0.92
Other	0.89	0.02	0.84	0.92	0.89	0.02	0.84	0.93
Private	0.89	0.02	0.85	0.91	0.90	0.02	0.87	0.93
TBI Severity								
Mild	0.91	0.01	0.88	0.93	0.92	0.01	0.89	0.94
Moderate	0.92	0.01	0.89	0.93	0.93	0.01	0.91	0.94
Severe	0.76	0.05	0.65	0.85	0.77	0.05	0.66	0.86

Note: Asymp. LCL = Asymptotic Lower Confidence Limit; Asymp. UCL = Asymptotic Lower Confidence Limit; --= Not applicable.

Age demonstrated small, but statistically significant associations with both OT and PT (ORs=1.02, 95% CI [1.01, 1.03]) (Table 5). Specifically, for each one-year increase in age, older patients were 1.02 times more likely to receive rehabilitation services relative to their younger counterparts. Compared to patients with a significant other, patients without a significant other were 0.82 times less likely to receive OT (OR= 0.82, 95% CI [0.68, 0.99]). Using patients with Medicaid insurance as the reference group, patients with private insurance were 1.35 times and 1.47 times more likely to receive OT (OR= 1.35, 95% CI [1.08, 1.70]); and PT (OR= 1.47, 95% CI [1.16, 1.87]), respectively. Likewise, patients with Medicare insurance were 1.49 times and 1.47 times more likely to receive OT (OR= 1.49, 95% CI [1.12, 1.98]); and PT (OR= 1.47, 95% CI [1.09, 1.98]), respectively. Using patients with severe TBI as the reference category, patients with moderate TBI were 3.39 times and 3.68 times more likely to receive OT (OR= 3.39, 95% CI [2.01, 5.70]); and PT (OR= 3.68, 95% CI [2.17, 6.24]), respectively. For each one-day increase in the length of stay, patients with longer length of stay were 1.23 times more likely to receive both OT and PT services (ORs = 1.23, 95% CIs [1.18, 1.27]). Patients with lesser comorbidity burden (i.e., functional comorbidity index [FX-TBI-CI] scores) were 1.05 times more likely to receive both OT and PT services (ORs = 1.05, 95% CIs [0.99, 1.08]) compared to patients with greater comorbidity burden. On the other hand, sex, race/ethnicity, and all four SDoH variables did not show significant associations with the receipt of either therapy service (p-values= 0.09 – 0.95). Figures 2 to 5 illustrate the pairwise comparisons between insurance type sub-groups and TBI-severity sub-groups for the odds of receiving rehabilitation services.

Table 5. Results of pairwise Comparisons (odds ratios) of receiving rehabilitation services.

	Received OT				Received PT			
	OR	SE	95% CI	*p*-value	OR	SE	95% CI	*p*-value
Intercept	0.45	0.34	[0.11, 1.99]	0.29	1.24	0.99	[0.26, 6.08]	0.79
Age (year)	1.02	0.003	**[1.01, 1.03]**	**<.001**	1.02	0.003	**[1.01, 1.03]**	**<.001**
Significant other								
No / Yes	0.82	0.08	**[0.68, 0.99]**	**0.04**	--	--	--	--
Insurance Type								
Private / Medicare	0.91	0.13	[0.68, 1.21]	0.50	1.00	0.16	[0.74, 1.36]	1.00
Private / Medicaid	1.35	0.16	**[1.08, 1.70]**	**0.01**	1.47	0.18	**[1.16, 1.87]**	**<.001**
Private / VA	1.38	0.32	[0.87, 2.17]	0.17	1.34	0.33	[0.83, 2.16]	0.24
Private / Other	0.96	0.17	[0.68, 1.34]	0.79	1.10	0.20	[0.77, 1.55]	0.61
Medicare / Medicaid	1.49	0.22	**[1.12, 1.98]**	**0.01**	1.47	0.23	**[1.09, 1.98]**	**0.01**
Medicare / VA	1.52	0.39	[0.92, 2.51]	0.10	1.34	0.36	[0.79, 2.27]	0.28
Medicare / Other	1.06	0.21	[0.72, 1.55]	0.78	1.10	0.22	[0.74, 1.63]	0.65
Medicaid / VA	1.02	0.24	[0.65, 1.61]	0.93	0.91	0.22	[0.56, 1.47]	0.70
Medicaid / Other	0.71	0.12	**[0.51, 0.98]**	**0.04**	0.75	0.13	[0.54, 1.04]	0.08
VA / Other	0.69	0.18	[0.43, 1.16]	0.17	0.82	0.23	[0.48, 1.41]	0.47
TBI Severity								
Mild / Moderate	0.88	0.10	[0.70, 1.09]	0.24	0.86	0.10	[0.69, 1.08]	0.20
Mild / Severe	2.97	0.83	**[1.71, 5.14]**	**<.001**	3.17	0.90	**[1.82, 5.54]**	**<.001**
Moderate / Severe	3.39	0.90	**[2.01, 5.70]**	**<.001**	3.68	0.99	**[2.17, 6.24]**	**<.001**
Length of stay (days)	1.23	0.02	**[1.19, 1.27]**	**<.001**	1.23	0.02	**[1.18, 1.27]**	**<.001**
FX-TBI-CI	0.95	0.02	**[0.91, 0.99]**	**0.02**	0.95	0.02	**[0.89, 0.98]**	**<.001**

Note: OR = Odd ratio; SE = Standard error; CI= Confidence intervals; Bold values= p <0.05; -- = Not applicable; OT= Occupational therapy; PT= Physical therapy; The reference groups in all pairwise comparisons are the groups listed after the forward slash.

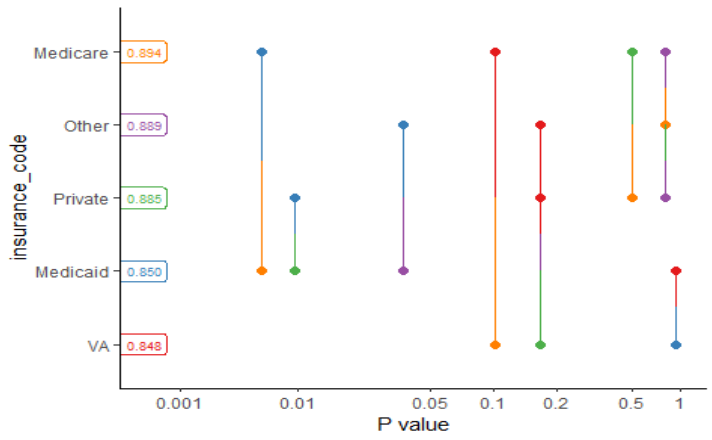

Figure 2. Insurance type groups

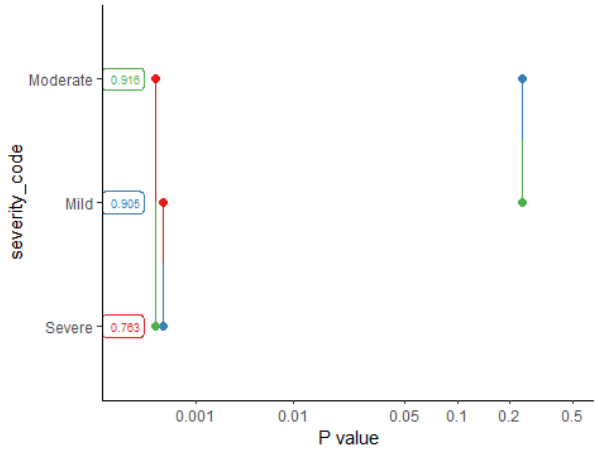

Figure 3. TBI severity groups

Note: OT service graphs. Graphs illustrating the estimated probabilities and odd ratios of receiving OT services. X-Axis: in both figures represents the *p*-value; Y-Axis: Probability of each group, arranged from smallest (at the bottom) to largest (at the top), Colored lines: Pairwise Comparisons (odds ratios). In Figure 2. using patients with Medicaid insurance as the reference group (probability= 0.85), patients with private insurance (probability= 0.89) were 1.35 times likely to receive OT (OR= 1.35, 95% CI [1.08, 1.70], *p*-value=0.01). In Figure 3. using patients with severe TBI as the reference category (probability= 0.76), patients with moderate TBI (probability= 0.92) were 3.39 times more likely to receive OT (OR= 3.39, 95% CI [2.01, 5.70], *p*-value<.001).

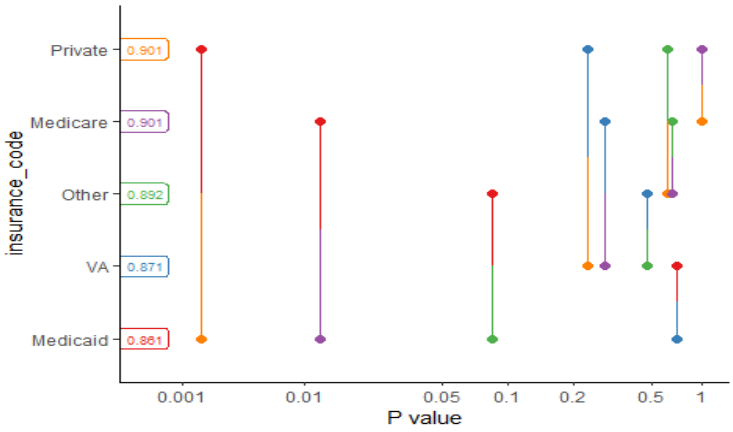

Figure 4. Insurance type groups

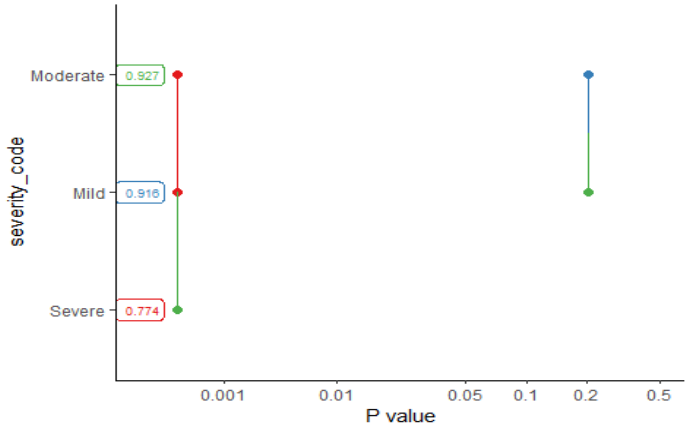

Figure 5. TBI severity groups

Note: PT service graphs. Graphs illustrating the estimated probabilities and odd ratios of receiving PT services. X-Axis: in both figures represents the *p*-value; Y-Axis: Probability of each group, arranged from smallest (at the bottom) to largest (at the top), Colored lines: Pairwise Comparisons (odds ratios). In Figure 4. using patients with Medicaid insurance as the reference group (probability= 0.86), patients with private insurance (probability= 0.90) were 1.47 times more likely to receive PT (OR= 1.47, 95% CI [1.16, 1.87, *p*-value<.001). In Figure 5. using patients with severe TBI as the reference category (probability= 0.77), patients with moderate TBI (probability= 0.93) were 3.68 times more likely to receive PT (OR= 3.68, 95% CI [2.17, 6.24], *p*-value<.001.

Timing of Rehabilitation Services

For hypothesis 2, which aimed to examine the influence of community-level SDoH variables, individual sociodemographic, and clinical factors on the time to first rehabilitation services encounter, we conducted Cox regression analyses (time-to-event analyses). All predictor variables in the OT model satisfied the proportional hazards assumption (Table 6). The large *p*-values associated with these variables indicate that there was insufficient evidence to reject the assumption and assume that the hazard ratios for the OT model remained constant over time. Conversely, in the PT model, Length of Stay violated the proportional hazards assumption, as indicated by a small *p*-value ($p < 0.001$). This violation provides strong evidence against the null hypothesis, leading to the conclusion that the proportional hazards assumption was not met. In practical terms, this implies that the hazard ratios for the PT model were not consistent over time.

Table 6. Testing proportional hazards assumption.

	OT			PT		
	Chi-squared	Df	*p*-value	Chi-squared	Df	*p*-value
Community level SDoH variables						
Income	0.01	1	0.94	0.00	1	0.99
High School attainment	2.59	1	0.11	1.04	1	0.31
Bachelors' attainment	0.05	1	0.82	0.01	1	0.94
Residence location	0.68	1	0.41	0.61	1	0.44
Age (years)	0.51	1	0.48	0.24	1	0.62
Sex	0.02	1	0.90	0.00	1	0.98
Significant other	0.36	1	0.55	0.00	1	0.97
Race/Ethnicity	5.61	4	0.23	5.98	4	0.20
Insurance Type	1.54	4	0.82	2.68	4	0.61
TBI severity	3.78	2	0.15	4.93	2	0.09
Length of Stay (days)	2.09	1	0.15	14.50	1	**<0.001**
FX-TBI-CI	0.67	1	0.41	3.37	1	0.07

Note: Df = Degrees of Freedom; Bold value= $p < 0.001$; SDoH= Social Determinants of Health; OT= Occupational therapy; PT= Physical therapy.

To address the violation of the proportional hazard assumption in the PT model, we included an interaction term between patients' length of stay (LOS) and time to PT service (in days) in the model. Age demonstrated small yet statistically significant associations with time to receive both OT and PT (HRs=1.01, 95% CIs [1.00-1.01]) (Table 7). Compared to younger patients, older patients were 1.01 times more likely to experience shorter wait times to receive both rehabilitation services. Compared to non-Hispanic White individuals, Black individuals were 0.88 times less likely to experience shorter wait times to receive OT service only (HR=0.88, 95% CI [0.77-0.99]). Using patients with private insurance as the reference group, patients with Medicaid insurance were 0.90 times and 0.91 times less likely to experience shorter wait times to receive both OT (HR= 0.90, 95% CI [0.83-0.98]) and PT (HR= 0.91, 95% CI [0.83-0.98]) services. Using patients with mild TBI as the reference category, patients with severe TBI were 0.80 times less likely to experience shorter wait times to receive OT (HR= 0.80, 95% CI [0.65-0.98]). Patients with longer lengths of stay were 0.99 times and 0.94 times less likely to experience shorter wait times to receive OT (HR=0.99, 95% CI [0.99-1.00]), and PT services (HR=0.94, 95% CI [0.93-0.94]), respectively. Sex, significant other status, comorbidity burden, and all four SDoH variables did not exhibit significant associations with early onset of either therapy service.

Table 7. Results of Cox regression analyses for onset of OT and PT services.

	HR (95% CI)	
	Time to OT	Time to PT*
Community level SDoH variables		
Income	1.00 (1.00-1.00)	1.00 (1.00-1.00)
High School	0.99 (0.99-1.00)	1.00 (0.99-1.00)
Bachelors	1.00 (0.99-1.00)	0.99 (0.99-1.00)
Residence (ref. = Rural)		
Urban	0.94 (0.85-1.05)	0.99 (0.98-1.10)
Age (years)	**1.01 (1.00-1.01)**	**1.01(1.00-1.01)**
Sex (ref. = Female)	0.94 (0.88-0.99)	0.96 (0.90-1.01)
Significant other (ref.= No)	1.06 (0.99-1.13)	1.05 (0.99-1.11)

Race/Ethnicity (ref. = White)		
Black	**0.88 (0.77-0.99)**	0.95 (0.84-1.08)
Hispanic	1.02 (0.93-1.11)	0.97 (0.89-1.06)
Multiple race	1.00 (0.81-1.25)	1.00 (0.81-1.24)
Other	1.09 (0.94-1.26)	1.06 (0.91-1.22)
Insurance Type (ref. = Private)		
Medicare	1.01 (0.92-1.09)	0.99 (0.91-1.08)
Medicaid	**0.90 (0.83-0.98)**	**0.91 (0.83-0.98)**
VA	0.88 (0.73-1.06)	0.88 (0.73-1.06)
Other	1.05 (0.92-1.18)	1.01 (0.89-1.14)
TBI severity (ref. = Mild)		
Moderate	1.08 (0.99-1.17)	1.07 (0.99-1.16)
Severe	**0.80 (0.65-0.98)**	0.90 (0.73-1.10)
LOS (days)	**0.99 (0.99-1.00)**	**1.08 (1.07-1.09)**
LOS by time to PT (days)*	--	**0.94 (0.93-0.94)**
FX-TBI-CI	0.99 (0.98-1.01)	0.99 (0.98-1.00)

Note: HR = Hazard ratio; Ref. = reference category; SDoH= Social Determinants of Health; VA= Veterans Affairs; LOS = Length of stay; FX-TBI-CI = functionally relevant TBI comorbidity index; Bold value= p <0.05; *= PT model with interaction term; -- = N/A

DISCUSSION

This study is among the first to examine the relationship between community-level SDoH and access to and timing of rehabilitation services among patients with TBI in acute care settings. Several of the person-level factors were associated with both access to and timing of rehabilitation services. However, none of our community-level SDoH variables were associated with either outcome. Our findings can inform future research exploring the impact of community-level SDoH on access to and timing of rehabilitation services among individuals with TBI in acute care settings.

We hypothesized that patients with social risk factors such as lower median income and education level, would exhibit a reduced likelihood of receiving rehabilitation services. Further, even if these individuals did receive such services, we anticipated they would wait a longer time

to receive those rehabilitation services, even after adjusting for patient-level risk factors. The results did not support these hypotheses.

We did observe a positive association between patient age and access to and timing of OT and PT services in acute care. Particularly, older patients were more likely to access rehabilitation services and experience shorter wait times. This finding aligns with previous studies indicating that older patients received rehabilitation services more promptly (Hargreaves et al., 2015; Robards et al., 2019). In our study, older patients are representing those with Medicare health insurance, which facilitates accessibility to rehabilitation services and subsequent reimbursement. Specifically, Medicare designed primarily for individuals aged 65 and older comprises specific provisions that facilitate accessibility to rehabilitation services and ease the reimbursement process. Unlike private insurance, which may vary in coverage and eligibility criteria. This distinction between Medicare and private insurance highlights a relevant factor contributing to the positive association between patient age and access to and timing of OT and PT services in acute care. More studies on the influence of age on access to and timing of rehabilitation services across different settings are necessary to identify potential differences in accessibility to rehabilitation services while accounting for socioeconomic status, or types of health care insurance.

We also observed a significant association between the presence of a significant other and the likelihood of receiving OT services. Individuals without a significant other were 0.82 times less likely to receive OT services. This finding aligns with the prior research indicating that patients who have a significant other (i.e., a spouse or caregiver) are more likely to have better access to healthcare services (Albrecht et al., 2017; Hao et al., 2020; Lin et al., 2022; Owolabi et al., 2023). It is possible that patients with a spouse or caregiver have an advocate to request more

services and that perhaps patients without a significant other need a 'patient advocate'. Several studies reported that presence of a significant other may affect patients' decision in selecting a facility, providers, or access to healthcare services (Rodakowski et al., 2017; Torbica et al., 2015; Wolff & Roter, 2011). Future research is needed to examine the impact of having social support on access to healthcare services in different settings and among various populations. Such investigations can provide a more comprehensive understanding of the multifaceted role of social support in facilitating healthcare access, ultimately aiding in the development of more inclusive and effective healthcare strategies.

Our findings showed that compared to non-Hispanic White, Black individuals experienced delays in receiving OT services (HR= 0.88, 95% CI [0.77-0.99]). This result aligns with the existing literature indicating that non-Hispanic White patients are more likely to obtain high quality health care and rehabilitation services relative to other race/ethnicity groups (Albright et al., 2020; Cancel-Tirado et al., 2018; Meagher et al., 2015; Schoenfeld et al., 2019). Disparities in access to health care services among different racial and ethnic groups may be due to several determinants such as lower income, and lack of health insurance (Cancel-Tirado et al., 2018; Meagher et al., 2015). As a result, racial minority patients often encounter barriers (e.g., lack of education, lack of health insurance, lack of transportation, and geographic region) that restrict their access to high-quality healthcare and rehabilitation services across various settings (Albright et al., 2020; Cancel-Tirado et al., 2018; Gao et al., 2018; Keeney et al., 2017a; Meagher et al., 2015; Schoenfeld et al., 2019). Future research should prioritize an in-depth exploration of the impact of these social barriers on the accessibility of rehabilitation services. Understanding the complex dynamics underlying these disparities is essential for the

development of targeted interventions aimed at reducing healthcare inequalities among diverse racial and ethnic populations.

Using patients with Medicaid insurance as the reference group, we found that patients with private insurance had substantially greater odds of receiving OT (OR= 1.35, 95% CI [1.08, 1.70]) and PT (OR=1.47, 95% CI [1.16, 1.87]) services. Using patients with private insurance as the reference group, patients with Medicaid experienced a longer wait time to receive OT (HR=0.90, 95% CI [0.83-0.98]) and PT (HR=0.91, 95% CI [0.83-0.98]) services. This result aligns with prior research, which consistently highlights the challenges faced by patients with Medicaid insurance in obtaining early access to healthcare services (e.g., lack of providers who accept Medicaid insurance, or limited spots that providers will allow for Medicaid) (Albrecht et al., 2017; Alcalá et al., 2018; Gao et al., 2018). Future research should investigate how many patients with Medicaid were admitted with Medicaid versus how many patients receive Medicaid (if any) while in the hospital. It could be that patients without insurance end up with Medicaid and are a different category/comparison group. Such research can provide valuable insights into the measures needed to address these disparities and ensure equitable access to healthcare services for all individuals, regardless of their insurance status.

Our findings revealed significant differences in access to rehabilitation services based on TBI severity and comorbidity burden. Our results indicated that compared to patients with severe TBI, those with mild or moderate TBI had greater odds of receiving both OT (Mild TBI OR=2.97, 95% CI [1.71, 5.14]; Moderate TBI OR=3.39, 95% CI [2.01, 5.70]) and PT (Mild TBI OR=3.17, 95% CI [1.82, 5.54]; Moderate TBI OR = 3.68, 95% CI [2.17, 6.24]) services. As comorbidity burden increased, likelihood of receiving either OT or PT services decreased (ORs = 0.95, 95% CIs [0.89, 0.98]). When considering the timing of rehabilitation services, with mild

TBI as a reference group, those with severe TBI had experienced a longer time to receive OT (HR=0.80, 95% CI [0.65-0.98]) service. These findings are consistent with prior research indicating that patients with severe TBI and greater comorbidity burden tend to face longer delays in the onset of rehabilitation services (Béavogui et al., 2015; Mehmood et al., 2021b). In our sample, patients with severe TBI may represent those patients with greater comorbidity burden and more medical complications such as paroxysmal sympathetic hyperactivity (PSH) that may pose a barrier to early onset of rehabilitation services (Deshpande et al., 2017; Mathew et al., 2016; Mez et al., 2017). Future research should examine the influence of TBI severity level and comorbidity burden on the onset of rehabilitation services. This is essential for guiding efforts aimed at ensuring timely and equitable access to rehabilitation services, which, in turn, can enhance patients' independence in self-care and mobility tasks and contribute to their overall well-being.

Our study revealed a significant relationship between length of stay and access to and timing of OT and PT services. Our findings indicated that patients with longer stays were more likely to have access to OT (OR= 1.23, 95% CI [1.19, 1.27]) and PT (OR=1.23, 95% CI [1.18, 1.27]) services. This finding is consistent with previous literature indicating that longer LOS was associated with receiving more rehabilitation services (Woznowski-Vu et al., 2015). On the other hand, our results showed that patients with longer stays experienced a longer time to receive OT (HR=0.99, 95% CI [0.99-1.00]) and PT (HR=0.94, 95% CI [0.93-0.94]) services. The link between LOS and access to and timing of rehabilitation services may be attributed to patients' functional or mobility status. In certain cases, individuals with TBI may require an extended duration for recovery to attain more capabilities that enable them to actively participate in therapeutic sessions. Further studies are needed to examine the impact of patients’ functional and

mobility levels and their associations with access to and timing of rehabilitation services. These investigations can offer valuable insights into tailoring rehabilitation services to meet the specific needs of patients at different stages of recovery, ensuring that access and timing are optimized for each individual's unique circumstances.

Regarding SDoH, our findings deviate from previous research, as none of our community-level SDoH variables were associated with accessibility or timing of OT or PT services. These findings are inconsistent with prior studies indicating that patients' income, educational attainment, and residence location were associated with accessibility to rehabilitation services in various settings. Previous research reported that patients with higher median income are more likely to have higher quality health care services (Cherla et al., 2018; Chokshi, 2018). Several studies found that patients living in urban areas are more likely to have early access to health care services, relative to those living in rural areas (Cancel-Tirado et al., 2018; Graves et al., 2019; Megan, 2021). To gain a deeper understanding of these unexpected findings, further research is needed. It is essential to ascertain whether the SDoH variables we employed, including community-level education, income, and rurality, were too diffuse (e.g., considering only the first three digits of zip codes) to adequately capture the individual experiences and impacts on care. Alternatively, it may be that, in the context of patients hospitalized with TBI, community-level factors do not significantly influence access to and timing of rehabilitation services.

Study Limitations

This study has a few limitations. First, the use of EHR data may involve missing information, misclassifications, coding, and reporting errors. Further, our study was limited to 14 hospitals within a single large health system and the findings may not generalize to other health

systems. Future research should replicate findings in additional health systems to determine if results translate to geographically diverse patients with TBI. Our dataset had no information about prior health status; thus, future research should explore the influence of patients' prior health status on onset of rehabilitation services. Our dataset lacked information about the referral date to rehabilitation services; therefore, future research should include referral dates to better address the timing of rehabilitation services in acute care. All SDoH variables we incorporated into this study were based on community-level data. While our findings revealed no significant associations, it is crucial for future research to investigate the impact of individual-level SDoH on the onset of rehabilitation services among individuals with TBI. This shift towards examining individual-level SDoH variables can offer a more nuanced perspective on the potential determinants of rehabilitation service accessibility and timing.

CONCLUSION

We examined whether SDoH are associated with, first, access to rehabilitation services among adults hospitalized for TBI and, second, duration to first rehabilitation encounter among those who did receive services. While the findings revealed no significant relationships between these community-level SDoH variables and access to or time of acute rehabilitation services, several individual-level variables exhibited clear and meaningful associations with both access to and timing of therapy services. This study provides a foundational understanding of the factors influencing access to and timing of rehabilitation services for adults with TBI. However, there is an ongoing need for more comprehensive research to investigate individual-level SDoH variables and to refine our understanding of the specific SDoH that may influence therapy service accessibility and timing. This collective knowledge will enable therapists to better tailor

their efforts, ensuring that all TBI patients receive equitable and timely access to rehabilitation services, ultimately enhancing their overall well-being and recovery.

CHAPTER THREE: REHABILITATION SERVICES UTILIZATION AND POST-ACUTE DISCHARGE DESTINATION AMONG ADULTS WITH TRAUMATIC BRAIN INJURY: THE MODERATING EFFECT OF FUNCTIONAL AND PHYSICAL PERFORMANCE AT DISCHARGE

OVERVIEW

Objective: To investigate whether the relationships between acute care occupational therapy (OT) and physical therapy (PT) utilization and community discharge are moderated by functional or physical performance at discharge among individuals hospitalized with traumatic brain injury (TBI).

Setting: 14 acute care hospitals in the state of Colorado.

Participants: 5,599 adults hospitalized with TBI between June 2018 and April 2021.

Design: In a secondary analysis of de-identified electronic health record (EHR) data, multivariable moderation logistic regression models were performed to calculate odds ratios (ORs) for the likelihood of community discharge among patients who utilized OT/PT services.

Main Measures: Functional (activities of daily living [ADL]) and physical (mobility) performance at discharge, OT/PT utilization, and community discharge.

Results: Overall, 67% of patients discharged to the community. Mean age of the sample was 55 years (SD = 20 years). A majority of participants were male (64%) and non-Hispanic white (72%). Mean hospital length of stay was 6 days (SD = 6 days). Both OT/PT utilization (OT: OR= 1.21, 95% CI [1.11, 1.33]; PT: OR= 1.22, 95% CI [1.14, 1.30]) and discharge ADL/mobility scores (ADL: OR= 1.34, 95% CI [1.30, 1.39]; mobility: OR= 1.38, 95% CI [1.33, 1.42]) were significantly and positively associated with community discharge. The OT/PT

utilization-by-discharge ADL/mobility interaction terms yielded slightly negative, but statistically significant moderation effects in both models (ORs= 0.99, 95% CIs [0.98, 1.00]); indicating the magnitude of the OT/PT utilization effect diminished as ADL/mobility scores increased. Several sociodemographic characteristics and clinical factors were also independently associated with community discharge in both models (*p*-values <0.001 - 0.04).

Conclusion: Greater OT/PT utilization was associated with increased odds of community discharge. Similarly, higher ADL/mobility scores at discharge were associated with increased odds of community discharge. The small, but statistically significant negative interaction terms in both models indicated that the magnitude of the OT/PT utilization effect diminished as ADL/mobility scores increased. The findings from this study can inform occupational and physical therapists' efforts aimed at ensuring a safe community discharge for patients with TBI.

Rehabilitation Services Utilization and Post-Acute Discharge Destination Among Adults with Traumatic Brain Injury: The Moderating Effect of Functional and Physical Performance at Discharge

Introduction

Traumatic brain injury (TBI) is a pressing public health concern in the US, with approximately 2.5 million TBI-related emergency department visits, 288,000 TBI-related hospitalizations, and 61,000 TBI-related deaths reported each year (Centers for Disease Control and Prevention, 2019). Notably, TBI is associated with high rates of disability, including limitations in performing basic activities of daily living (ADLs), such as bathing, dressing, eating, or toileting, and/or in performing physical tasks, such as mobility (Klima et al., 2019; Jessica Lo et al., 2021; Whiteneck et al., 2016).

Community discharge is generally viewed as an indicator of high-quality health services provided in acute care settings (Department of Health and Human Services [HHS], 2019). Several studies have addressed the positive impacts of community discharge on patients, including higher levels of functional independence (Brown et al., 2020; Souesme et al., 2022; Werner et al., 2019), fewer cognitive or behavioral issues (Arya et al., 2022; Souesme et al., 2022), lower healthcare cost (Chevalley et al., 2022; Werner et al., 2019), and enhanced quality of life (Arya et al., 2022; Olsson et al., 2020). Occupational and physical therapy services during the acute stay have been associated with a higher rate of community discharge (Kanchan et al., 2018; O'Brien & Zhang, 2018; Roberts et al., 2016; Souesme et al., 2022; Thorpe et al., 2018).

Occupational and physical therapists in acute care settings analyze patients' functional

and physical performance limitations and gather other relevant information (e.g., living situation) to tailor treatment to enable a safe community discharge (Jette et al., 2014). However, there is a lack of studies that provide empirical support for factors explaining the relationship between acute care OT and PT utilization and discharge disposition.

A primary focus of acute care rehabilitation services is to improve patients' functional and physical performance (Ejlersen Wæhrens & Fisher, 2007). Two acute care studies have found that rehabilitation services are associated with improved functional and physical performance in patients with TBI (Trevena-Peters et al., 2018; Zarshenas et al., 2019). Additionally, increased frequency of rehabilitation services leads to greater functional and physical gains at the time of discharge from acute care among patients with TBI (Kanchan et al., 2018; Zarshenas et al., 2019).

In turn, patients with TBI with higher functional and physical scores may be more likely to discharge to the community, as higher functional and physical performance during acute care rehabilitation ideally translates into safe performance of daily activities and basic mobility within a patient's home environment (Jette et al., 2003). Several studies have examined the relationship between functional and physical status and discharge destination following acute care among patients with TBI, finding that TBI survivors who made larger functional and physical gains were more likely to discharge to the community (Horn et al., 2015; Oyesanya, 2020; van Baalen et al., 2008). To date, no study has examined whether functional/ physical performance at discharge influences the relationship between acute care OT/PT services utilization and community discharge. Understanding potential mechanisms by which OT/PT utilization and community discharge are related may inform efforts to enhance the type or amount of acute care OT/PT services delivered to individuals with TBI to maximize safe community discharge.

The purpose of this study was to investigate whether the relationship between acute care OT/PT utilization and community discharge is moderated by functional or physical performance at discharge. We hypothesized that patients with greater OT/PT utilization would be more likely to have community discharge and that this relationship would differ depending on patients' functional or physical performances at discharge.

METHODS

Participants and procedure

This was a retrospective cross-sectional study of de-identified electronic health record (EHR) data for patients admitted to 14 trauma centers, levels I to IV, within a single large health system in the state of Colorado. The study included EHR data from 401,350 patients admitted and discharged between June 2018 and April 2021. Inclusion criteria were an adult (aged ≥ 18 years), admitted to the hospital with a TBI diagnosis based on International Classification of Diseases (ICD-10) codes for admission, and had at least one OT/PT evaluation/treatment session. We excluded patients who did not survive the hospitalization or were missing data on key variables of interest. These data were validated, de-identified, organized, and supported by the Health Data Compass Data Warehouse project (healthdatacompass.org). After applying the inclusion criteria, the final sample consisted of 5,599 adults (Figure 6). Although we excluded subjects with missing data, close examination of patients with missing data revealed no systematic differences in the independent or dependent variables compared to patients without missing data. A signed data-use agreement was in-place, and the study was approved by Colorado State University Institutional Review Board. The *Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)* reporting guidelines were applied to this study (von Elm et al., 2014). See (appendix B) for more information about *STROBE* statements.

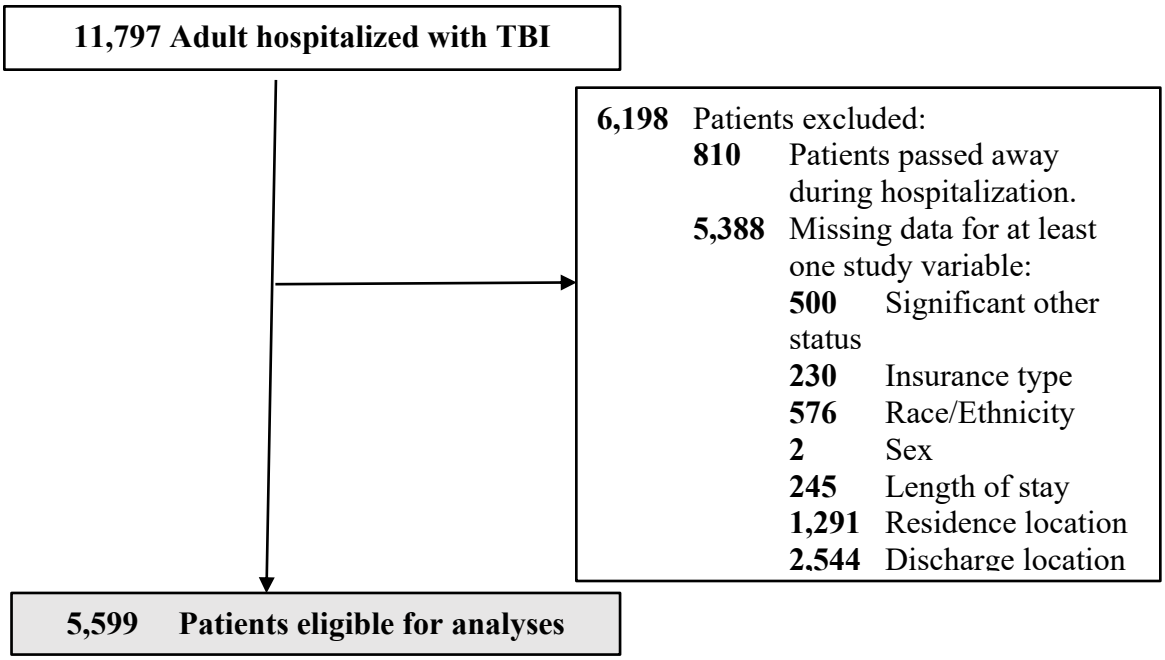

Figure 6. Cohort Selection Diagram

Measures

OT/PT utilization

OT/PT utilization was measured using units encountered of OT/PT (e.g., 1 unit = ≥ 8 minutes through 22 minutes) during the acute care stay. Additional details about the service units and their equivalent billed minutes can be found in appendix C.

Functional/physical performance at discharge

Patients functional (i.e., basic self-care) or physical (i.e., basic mobility) performance at discharge was measured using the Activity Measure for Post-Acute Care (AM-PAC^{TM}) "6-Clicks" daily activity inpatient short form (Jette et al., 2014). The AM-PAC "6-Clicks" daily activity inpatient short form score ranges from 6 (i.e., indicating that the patient needs total assistance) to 24 (i.e., indicating that the patient requires no assistance) (Jette et al., 2014). OT practitioners rate the following six activities of daily living (ADLs) according to level of assistance needed on a scale of 1 (“total”) to 4 (“none”): upper body dressing, lower body

dressing, bathing, toileting, grooming, and eating (Jette et al., 2014). PT practitioners rate the following six activities of physical performance according to level of assistance needed on a scale of 1 (“total”) to 4 (“none”): bed mobility, sit to stand, supine to sit, seated transfers, ambulation, and ascending stairs (Jette et al., 2014). The AM-PAC "6-Clicks" has very high internal consistency among OT and PT practitioners: Cronbach’s alpha = 0.91and 0.96 for ADL and mobility assessments, respectively (Jette et al., 2014). The AM-PAC "6-Clicks" scores are standardized (Jette et al., 2014), with higher scores indicating greater ADL performance (range = 17.07 – 57.54), as well as greater basic mobility abilities (range = 23.55 – 61.14).

Community discharge

We constructed a binary indicator of community discharge (yes/no). Community discharge included home and other supported living facilities (e.g., senior living facility/ assisted living facility). A non-community discharge includes all institutional discharges including long term care, mental health facility, nursing facility, rehabilitation facility, short term hospital, and skilled nursing facility.

Covariates

We included person-level factors such as age (years); sex (female/male); race/ethnicity (White, Black, Hispanic, Multiple race, and Other [e.g., Asian, American Indian, Alaska native, native Hawaiian, and Pacific Islander]); presence of a significant other (yes/no); insurance type (e.g., Medicare, Medicaid, VA, Others, and Private); length of stay (days); comorbidity burden (using Functionally relevant TBI Comorbidity Index [Fx-TBI-CI] (Kumar et al., 2022)), and TBI severity (e.g., Mild; Moderate; and Severe (Defense and Veterans Brain Injury Center, 2015)) as covariates. The Fx-TBI-CI is a method used to categorize patients’ with TBI comorbidities based on the International Classification of Diseases (ICD-10) diagnosis codes obtained from hospital

administrative data (Kumar et al., 2022). The Fx-TBI-CI was calibrated based on the function of individuals with TBI receiving inpatient care (Kumar et al., 2022). We constructed a weighted summary index according to Kumar et al. to evaluate comorbidity burden (2022). We used ICD-10 diagnosis codes obtained from the Defense and Veterans Brain Injury Center (DVBIC) to classify TBI severity: mild, moderate, and severe (Defense and Veterans Brain Injury Center, 2015).

Data Analysis

Descriptive statistics (e.g., means, standard deviations, percentages) were calculated, both for the total sample and stratified by community discharge setting. We used bivariate analyses to examine unadjusted differences in patient characteristics between discharge groups: Chi-square, independent t-tests, and ANOVAs. Specifically, Chi-square and ANOVA analyses were conducted to assess the association between dichotomous and categorical variables (i.e., three or more levels), respectively, and the dependent variable (e.g., community discharge [yes/no]). Independent t-tests were utilized to examine the association between all continuous variables and the dependent variable (e.g., community discharge [yes/no]). Multivariable moderation logistic regression models were used community discharge status as the dependent variable and rehabilitation services utilization (e.g., OT, and PT) and patients functional (i.e., ADL) or physical (i.e., mobility) performance at discharge as the main predictors of interest. In the OT model, we computed the main effect of OT utilization on community discharge, the main effect of functional performance (ADL) scores at discharge on community discharge, and the moderating effect of ADL scores on the relationship between OT utilization and community discharge by including an OT utilization-by-discharge ADL score interaction term. Similarly, in the PT model, we computed the main effect of PT utilization on community discharge, the main

effect of physical performance (mobility) scores at discharge on community discharge, and the moderating effect of mobility scores on the relationship between PT utilization and community discharge by including a PT utilization-by-discharge mobility score interaction term. Estimates (e.g., odds ratios, confidence intervals) were adjusted for age, sex, race/ethnicity, presence/absence of a significant other, insurance type, length of stay, comorbidity burden, and TBI severity levels. Statistical significance was evaluated at $\alpha = .05$ for all parameter estimates. All analyses were performed using R (Version 4.3.1) (R Core Team, 2023).

RESULTS

Among the 5,599 patients included in the study, (67%) were discharged to the community (Table 8). There were statistically significant differences between OT/PT utilization, and discharge ADL/mobility scores on community discharge (*p*-values= <0.001 – 0.004). The mean OT utilization units was 4 (*SD*=4.1) and the average discharge ADL score was 19.8 (*SD*=4.3) (e.g., ADL score ranges from 6 (i.e., indicating that the patient needs total assistance) to 24 (i.e., indicating that the patient requires no assistance). The mean PT utilization units was 5 (*SD*=5.7) and the average discharge mobility score was 20.0 (*SD*=4.3) (e.g., Mobility score ranges from 6 (i.e., indicating that the patient needs total assistance) to 24 (i.e., indicating that the patient requires no assistance). The sample had a mean age of 54.7 years (*SD*=20.2), with the majority being male (64%), White (72%), and having no significant other (58%). The most common insurance type was Medicare (39%), followed by Medicaid (26%). Most patients experienced moderate TBI severity (83%). Results of the Chi-square and ANOVA analyses indicated statistically significant differences in community discharge with respect to patients' sex ($\chi^2(1) = 22.9$, *p*-value< 0.001), race/ethnicity (F(9.5, 6896.5)=7.7, *p*-value= 0.01), significant other status ($\chi^2(1) = 7.6$, *p*-value= 0.01), insurance type (F(412, 14683)=157, *p*-value< 0.001),

and TBI severity groups (F(8.7, 873.8)=55.4, *p*-value< 0.001). Results of bivariate t-test analysis showed that there were statistically significant associations between various variables such as age (t(5597)=18.6, *p*-value=0.02), length of stay (t(5597)=28.8, *p*-value< 0.001), and comorbidity burden (t(5597)=19.6, *p*-value< 0.001) with community discharge. See Table 8.

Table 8. Sample characteristics with descriptive summaries of community discharge.

	N (%)	Community Discharge, *n* (%)		*p*-value
		No	Yes	
Total	5599	1825 (32.6%)	3774 (67.4%)	
OT utilization, in units, mean (*SD*)*	3.9 (4.1)	4.91 (4.1)	3.35 (4.0)	**<0.001**
Discharge ADL score, in AM-PAC, mean (*SD*)*	19.8 (4.3)	17.1 (4.7)	21.3 (3.1)	**<0.001**
PT utilization, in units, mean (*SD*)*	5.1 (5.7)	6.4 (5.4)	4.4 (5.7)	**0.004**
Discharge Mobility score, in AM-PAC, mean (*SD*)*	20.0 (4.3)	17.2 (4.8)	21.5 (3.1)	**<0.001**
Age in years, mean (*SD*)	54.7 (20.2)	61.7 (19.5)	51.3 (19.6)	**0.02**
Sex				**<0.001**
Female	2002 (35.8%)	733 (13.1%)	1269 (22.7%)	
Male	3597 (64.2%)	1092 (19.5%)	2505 (44.7%)	
Race/Ethnicity				**<0.001**
White	4010 (71.6%)	1381 (24.7%)	2629 (47.0%)	
Black	341 (6.1%)	95 (1.7%)	246 (4.4%)	
Hispanic	877 (15.7%)	212 (3.8%)	665 (11.9%)	
Multiple race	103 (1.8%)	42 (0.8%)	61 (1.1%)	
Other	268 (4.8%)	95 (1.7%)	173 (3.1%)	
Significant other				**0.01**
Yes	2337 (41.7%)	714 (12.8%)	1623 (29.0%)	
No	3262 (58.3%)	1111 (19.8%)	2151 (38.4%)	
Insurance Type				**<0.001**
Medicare	2185 (39.0%)	998 (17.8%)	1187 (21.2%)	
Medicaid	1439 (25.7%)	358 (6.4%)	1081 (19.3%)	
VA	155 (2.8%)	33 (0.6%)	122 (2.2%)	
Other	396 (7.1%)	66 (1.2%)	330 (5.9%)	
Private	1424 (25.4%)	370 (6.6%)	1054 (18.8%)	
TBI Severity				**<0.001**
Mild	835 (14.9%)	207 (3.7%)	628 (11.2%)	
Moderate	4629 (82.7%)	1536 (27.4%)	3093 (55.2%)	
Severe	135 (2.4%)	82 (1.5%)	53 (0.9%)	
Length of stay in day, mean (*SD*)	5.8 (5.6)	8.7 (6.8)	4.4 (4.3)	**<0.001**
Community Density				0.50
Urban	5112 (91.3%)	1673 (29.9%)	3439 (61.4%)	
Rural	487 (8.7%)	152 (2.7%)	335 (6.0%)	
FX-TBI-CI, mean (*SD*)	1 (2.4)	1.9 (3.0)	0.6 (1.9)	**<0.001**

		Community Discharge, *n* (%)		
	N (%)	No	Yes	*p*-value

Note: SD=standard deviation; OT=Occupational therapy; PT=physical therapy; ADL= Activity of daily living; AM-PAC= Activity Measure for Post-Acute Care; FX-TBI-CI = functionally relevant TBI comorbidity index; *OT/PT utilization units & discharge ADL/Mobility scores only include the subset of patients who received those services n = 4585 and 4769, respectively; *p*-value for the bivariate analyses: Chi-square, t-test, and ANOVA; Bold value= Significant *p*-value <0.05.

There was sufficient evidence to suggest that OT/ PT utilization, and ADL/mobility score at discharge were good predictors of community discharge (*p*-values<0.001) (Table 9). OT/ PT utilization illustrated statistically significant positive associations with the log odds of community discharge for patients who received OT ($\hat{\beta}$= 0.19; *SE*= 0.05; *p*-value<0.001), and PT ($\hat{\beta}$= 0.20; *SE*= 0.03; *p*-value<0.001). Patients ADL and mobility scores at discharge demonstrated statistically significant positive associations with the log odds of community discharge for patients who received OT ($\hat{\beta}$= 0.30; *SE*= 0.02; *p*-value<0.001), and PT ($\hat{\beta}$= 0.32; *SE*= 0.02; *p*-value<0.001). Both OT and PT interaction terms (i.e., OT utilization-by-discharge ADL score & PT utilization-by-discharge mobility score) showed small but significant negative association with the log odds of community discharge ($\hat{\beta}$= -0.01; *SE*= 0.002; *p*-value<0.001). Age demonstrated statistically significant negative associations with the log odds of community discharge for patients who received OT and PT ($\hat{\beta}$= -0.02; *SE*= 0.002; *p*-value<0.001). Black and Hispanic patients were significantly and positively associated with the log odds of community discharge for patients who received OT (Black: $\hat{\beta}$= 0.53; *SE*= 0.19; *p*-value=0.01; Hispanic: $\hat{\beta}$= 0.39; *SE*= 0.12; *p*-value <0.001), and PT (Black: $\hat{\beta}$= 0.48; *SE*= 0.19; *p*-value=0.01; Hispanic: $\hat{\beta}$= 0.26; *SE*= 0.12; *p*-value=0.03) relative to their non-Hispanic White counterparts.

The presence of a significant other was significantly and positively associated with the log odds of community discharge for patients who received OT ($\hat{\beta}$= 0.48; *SE*= 0.09; *p*-

value<0.001), and PT ($\hat{\beta}$= 0.44; *SE*= 0.08; *p*-value<0.001) relative to patients with no significant other. Compared to patients with private insurance, patients with Medicare insurance were significantly and negatively associated with the log odds of community discharge for patients who received OT ($\hat{\beta}$= -0.42; *SE*= 0.12; *p*-value<0.001), and PT ($\hat{\beta}$= -0.39; *SE*= 0.12; *p*-value<0.001). In comparisons to patients with mild TBI, patients with severe TBI level were negatively associated with the log odds of community discharge for patients who received OT ($\hat{\beta}$= -0.83; *SE*= 0.31; *p*-value<0.001), and PT ($\hat{\beta}$= -0.68; *SE*= 0.29; *p*-value=0.02). Comorbidity burden score was significantly and negatively associated with the log odds of community discharge for patients who received OT ($\hat{\beta}$= -0.08; *SE*= 0.002; *p*-value<0.001), and PT ($\hat{\beta}$= -0.10; *SE*= 0.02; *p*-value<0.001). Longer lengths of stay in acute care was negatively associated with the log odds of discharge to the community for patients who received OT and PT ($\hat{\beta}$= -0.15; *SE*= 0.01; *p*-value<0.001). There was not sufficient evidence to suggest that the other covariates (i.e., sex, and residence location) were significantly associated with community discharge (*p*-values= 0.11 – 0.74). Table 9 presents the coefficient estimates from the logistic regression analysis.

Table 9. Regression coefficients results of moderation logistic regression models for community discharge.

	OT moderation model			PT moderation model		
	Beta coefficients	Standard error (SE)	*P*-value	Beta coefficients	Standard error (SE)	*P*-value
Intercept	-2.89	0.39	**<0.001**	-3.29	0.39	**<0.001**
OT utilization units	0.19	0.05	**<0.001**	--	--	**--**
Discharge ADL score (AM-PAC)	0.30	0.02	**<0.001**	--	--	**--**
OT utilization * Discharge ADL score	-0.01	0.002	**<0.001**	--	--	**--**
PT utilization units	--	--	**--**	0.20	0.03	**<0.001**
Discharge Mobility score (AM-PAC)	--	--	**--**	0.32	0.02	**<0.001**
PT utilization * Discharge Mobility score	--	--	**--**	-0.01	0.002	**<0.001**
Age (years)	-0.02	0.002	**<0.001**	-0.02	0.002	**<0.001**
Sex (ref. = Female)	0.03	0.08	0.74	-0.03	0.08	0.69
Race/Ethnicity (ref. = White)						
Black	0.53	0.19	**0.01**	0.48	0.19	**0.01**
Hispanic	0.39	0.12	**<0.001**	0.26	0.12	**0.03**
Multiple race	0.05	0.3	0.88	-0.28	0.29	0.33
Other	0.19	0.19	0.32	0.28	0.19	0.14
Significant other (ref.= No)	0.48	0.09	**<0.001**	0.44	0.08	**<0.001**
Insurance Type (ref. = Private)						
Medicare	-0.42	0.12	**<0.001**	-0.39	0.12	**<0.001**
Medicaid	0.22	0.13	0.08	0.27	0.13	**0.03**
VA	-0.22	0.28	0.44	-0.19	0.30	0.53
Other	0.54	0.21	**0.01**	0.56	0.21	**0.01**
TBI severity (ref. = Mild)						
Moderate	-0.23	0.12	**0.04**	-0.26	0.12	**0.03**
Severe	-0.83	0.31	**<0.001**	-0.68	0.29	**0.02**
Length of stay (days)	-0.15	0.01	**<0.001**	-0.15	0.01	**<0.001**
Residence (ref. = Rural)						
Urban	-0.21	0.14	0.15	-0.23	0.14	0.11
FX-TBI-CI	-0.08	0.002	**<0.001**	-0.10	0.02	**<0.001**

Note: OT= Occupational therapy; PT= Physical therapy; ADL= Activities of daily living; AM-PAC= Activity Measure for Post-Acute Care; Ref. = reference category; VA= Veterans Affairs; FX-TBI-CI = functionally relevant TBI comorbidity index; -- = Not applicable; Bold value= Significant *p*-value <0.05.

Probabilities of community discharge for each race/ethnicity, significant other status, insurance type, and TBI severity group are provided in Table 10. In the OT model, the estimated probability of community discharge was highest for Black individuals (0.76), followed by Hispanic individuals (0.74), and was lowest for White individuals (0.65). Similarly, in the PT model, the estimated probability of community discharge was highest for Black individuals (0.78), followed by Hispanic individuals (0.74), and was lowest for Multiple race individuals (0.63). The estimated probabilities of community discharge were highest among patients with a significant other (0.75; and 0.76) in both OT and PT model, respectively. Patients with other types of insurance had the highest estimated probability of community discharge (0.80; and 0.81) in both OT/PT models, followed by Medicaid insurance (0.74; and 0.76) in both OT/PT models, while patients with Medicare insurance had the lowest estimated probability of community discharge (0.60; and 0.62) in both OT/PT models, respectively. Among different TBI severities, the estimated probability of community discharge was highest for mild TBI (0.77; and 0.78) in both OT/PT models, followed by patients with moderate TBI (0.73; and 0.79), and severe TBI (0.60; and 0.64) in both OT/PT models, respectively.

Table 10. Results of the estimated probability of community discharge of the significant groups from the logistic regression analyses.

	OT moderation model				PT moderation model			
			Asymp				Asymp	
	Prob	(SE)	LCL	UCL	Prob	(SE)	LCL	UCL
Race/Ethnicity								
White	0.65	0.03	0.56	0.74	0.69	0.03	0.60	0.77
Black	0.76	0.04	0.62	0.86	0.78	0.04	0.65	0.87
Hispanic	0.74	0.03	0.63	0.82	0.74	0.03	0.64	0.82
Multiple race	0.67	0.07	0.44	0.84	0.63	0.07	0.40	0.81
Other	0.70	0.05	0.54	0.82	0.75	0.04	0.60	0.85
Significant other								
No	0.65	0.04	0.56	0.73	0.67	0.03	0.59	0.75
Yes	0.75	0.03	0.67	0.82	0.76	0.03	0.69	0.82
Insurance Type								
Medicare	0.60	0.04	0.49	0.71	0.62	0.04	0.52	0.72
Medicaid	0.74	0.03	0.64	0.82	0.76	0.03	0.67	0.84
VA	0.65	0.07	0.43	0.82	0.67	0.07	0.44	0.84
Other	0.80	0.04	0.67	0.89	0.81	0.04	0.68	0.89
Private	0.70	0.03	0.59	0.79	0.71	0.03	0.61	0.80
TBI Severity								
Mild	0.77	0.03	0.69	0.84	0.78	0.03	0.70	0.84
Moderate	0.73	0.02	0.66	0.79	0.73	0.02	0.66	0.79
Severe	0.60	0.08	0.39	0.77	0.64	0.07	0.45	0.79

Note: Prob= Probabilities; SE= Standard error; Asymp. LCL = Asymptotic Lower Confidence Limit; Asymp. UCL = Asymptotic Lower Confidence Limit; OT= Occupational therapy; PT= Physical therapy.

The moderating effect of those variables on the relationship between OT/PT utilization and community discharge was negative and statistically significant (ORs= 0.99, 95% CIs [0.98, 1.00]). This indicates that the magnitude of the OT/PT utilization effect diminished as ADL/mobility scores increased. The main effect of OT and PT utilization was significantly positively associated with community discharge: (OR= 1.21, 95% CI [1.11, 1.33]); (OR=1.22, 95% CI [1.14, 1.30]), respectively (Table 2.4). Specifically, patients with *greater* OT/PT utilization were 1.21 to 1.22 times more likely to discharge to the community. The main effect of

functional performance (ADL) / physical performance (mobility) scores at discharge demonstrated statistically significant positive associations with community discharge: (OR= 1.34, 95% CI [1.30, 1.39]); (OR=1.38, 95% CI [1.33, 1.42]), respectively. Meaning that patients with *higher* ADL/mobility performance scores at discharge were 1.34 to 1.38 times more likely to be discharged to the community.

Several covariates were significantly associated with community discharge. White individuals demonstrated statistically significant negative associations with community discharge relative to their Hispanic and Black counterparts in both models (OT model White vs. Hispanic (OR= 0.67, 95% CI [0.53, 0.87]), White vs. Black (OR=0.59, 95% CI [0.41, 0.86]); PT model White vs. Hispanic (OR= 0.76, 95% CI [0.61, 0.98]), White vs. Black (OR=0.62, 95% CI [0.43, 0.90]). This implies that non-Hispanic White patients were 0.67 to 0.76 times less likely to be discharged to community compared to their Hispanic counterparts in both OT and PT models. Similarly, non-Hispanic White patients 0.59 to 0.62 times less likely to be discharged to community compared to their Black counterparts in both OT and PT models. Age demonstrated statistically significant associations with community discharge (ORs=0.98, 95% CIs [0.97, 0.99]) in both OT and PT models. Specifically, for each one-year increase in age, older patients were 0.98 times less likely to be discharged to the community relative to younger patients. Compared to patients with significant others, patients with no significant other were less likely to experience community discharge (OR=0.62, 95% CI [0.53, 0.74]); (OR=0.64, 95% CI [0.55, 0.76]), for OT and PT models, respectively. Specifically, individuals without a significant other were 0.62 to 0.64 times less likely to experience community discharge. Using patients with Medicare insurance as the reference group, patients with private insurance were 1.48 to 1.53 times more likely to be discharged to the community (OT: OR= 1.53, 95% CI [1.20, 1.95]); (PT:

OR= 1.48, 95% CI [1.20, 1.95]). Using severe or moderate TBIs as reference categories, patients with mild TBI were 1.26 to 2.28 times more likely to be discharged to the community (OT model: Mild vs. moderate TBI OR= 1.26, 95% CI [1.00, 1.58]); Mild vs. Severe TBI OR= 2.28, 95% CI [1.23, 4.23]), PT model: Mild vs. moderate TBI OR= 1.30, 95% CI [1.03, 1.63]); Mild vs. Severe TBI OR= 1.97, 95% CI [1.11, 3.50]). Length of stay was associated with community discharge in both OT and PT models (ORs = 0.86, 95% CIs [0.84, 0.88]). Particularly, patients with longer length of stay were 0.86 times less likely to be discharged to the community relative to patients with shorter length of stay. Patients with greater comorbidity burden (i.e., functional comorbidity index [FX-TBI-CI] scores) were 0.91 to 0.93 times less likely to be discharged to the community (OR= 0.93, 95% CI [0.90, 0.96]) in OT model and (OR=0.91, 95% CI [0.88, 0.94]) in PT model. On the other hand, sex, and community density variables did not show significant associations with community discharge in either model (*p*-values= 0.11 – 0. 0.69). See Table 11.

Table 11. Results of pairwise comparisons (odds ratios) for community discharge.

	Community discharged							
	OT moderation model				PT moderation model			
	OR	SE	95% CI	*p*-value	OR	SE	95% CI	*p*-value
Intercept	0.06	0.02	**[0.02, 0.12]**	**<0.001**	0.04	0.01	**[0.02, 0.08]**	**<0.001**
OT utilization units	1.21	0.05	**[1.11, 1.33]**	**<0.001**	--	--	--	**--**
Discharge ADL score (AM-PAC)	1.34	0.02	**[1.30, 1.39]**	**<0.001**	--	--	--	**--**
OT utilization * Discharge ADL score	0.99	0.002	**[0.98, 1.00]**	**<0.001**	--	--	--	**--**
PT utilization units	--	--	--	**--**	1.22	0.04	**[1.14, 1.30]**	**<0.001**
Discharge Mobility score (AM-PAC)	--	--	--	**--**	1.38	0.02	**[1.33, 1.42]**	**<0.001**
PT utilization * Discharge Mobility score	--	--	--	**--**	0.99	0.002	**[0.98, 1.00]**	**<0.001**
Race/Ethnicity								
White / Other	0.83	0.15	[0.57, 1.21]	0.32	0.75	0.14	[0.52, 1.10]	0.14
White / Multiple race	0.96	0.28	[0.53, 1.73]	0.88	1.33	0.39	[0.75, 2.35]	0.33
White / Hispanic	0.67	0.08	**[0.53, 0.87]**	**0.002**	0.76	0.09	**[0.61, 0.98]**	**0.03**
White / Black	0.59	0.11	**[0.41, 0.86]**	**0.01**	0.62	0.12	**[0.43, 0.90]**	**0.01**
Other / Multiple race	1.15	0.40	[0.58, 2.30]	0.68	1.75	0.59	[0.90, 3.41]	0.09
Other / Hispanic	0.82	0.18	[0.54, 1.26]	0.37	1.01	0.22	[0.67, 1.54]	0.94
Other / Black	0.71	0.19	[0.43, 1.19]	0.20	0.82	0.21	[0.49, 1.35]	0.43
Multiple race / Hispanic	0.71	0.19	[0.38, 1.33]	0.28	0.58	0.18	[0.32, 1.06]	0.07
Multiple race / Black	0.62	0.18	[0.31, 1.22]	0.17	0.47	0.16	**[0.24, 0.90]**	**0.02**
Hispanic / Black	0.87	0.20	[0.57, 1.32]	0.51	0.81	0.17	[0.53, 1.22]	0.31
Age (year)	0.98	0.002	**[0.97, 0.98]**	**<0.001**	0.98	0.002	**[0.97, 0.99]**	**<0.001**
Significant other								
No / Yes	0.62	0.05	**[0.53, 0.74]**	**<0.001**	0.64	0.05	**[0.55, 0.76]**	**<0.001**
Insurance Type								
Private / Medicare	1.53	0.19	**[1.20, 1.95]**	**<0.001**	1.48	0.18	**[1.17, 1.89]**	**0.001**
Private / Medicaid	0.80	0.10	[0.63, 1.03]	0.08	0.76	0.09	**[0.59, 0.97]**	**0.03**
Private / VA	1.25	0.35	[0.72, 2.18]	0.44	1.21	0.36	[0.67, 2.17]	0.53
Private / Other	0.58	0.12	**[0.39, 0.87]**	**0.01**	0.57	0.12	**[0.38, 0.86]**	**0.01**

Medicare / Medicaid	0.53	0.07	**[0.40, 0.69]**	**<0.001**	0.51	0.07	**[0.39, 0.67]**	**<0.001**
Medicare / VA	0.82	0.24	[0.46, 1.45]	0.48	0.81	0.25	[0.44, 1.49]	0.50
Medicare / Other	0.38	0.08	**[0.25, 0.58]**	**<0.001**	0.39	0.08	**[0.25, 0.59]**	**<0.001**
Medicaid / VA	1.55	0.81	[0.89, 2.72]	0.12	1.59	0.48	[0.88, 2.87]	0.12
Medicaid / Other	0.72	0.15	[0.48, 1.09]	0.12	0.75	0.16	[0.50, 1.14]	0.17
VA / Other	0.47	0.15	**[0.24, 0.89]**	**0.02**	0.47	0.16	**[0.24, 0.93]**	**0.03**
TBI Severity								
Mild / Moderate	1.26	0.15	**[1.00, 1.58]**	**0.04**	1.30	0.15	**[1.03, 1.63]**	**0.03**
Mild / Severe	2.28	0.72	**[1.23, 4.23]**	**0.01**	1.97	0.58	**[1.11, 3.50]**	**0.02**
Moderate / Severe	1.81	0.54	**[1.01, 3.26]**	**0.04**	1.52	0.42	[0.89, 2.61]	0.13
Length of stay (days)	0.86	0.01	**[0.85, 0.88]**	**<0.001**	0.86	0.01	**[0.84, 0.88]**	**<0.001**
FX-TBI-CI	0.93	0.02	**[0.90, 0.96]**	**0.002**	0.91	0.02	**[0.88, 0.94]**	**<0.001**

Note: OR = Odd ratio; SE = Standard error; CI= Confidence intervals; Bold values= p <0.05; -- = Not applicable; OT= Occupational therapy; PT= Physical therapy; The reference groups in all pairwise comparisons are the groups listed after the forward slash.

Given that ADL/mobility score at discharge had a significant moderating effect on the relationship between OT/PT utilization and the likelihood of discharge to the community, we calculated the log odds of community discharge between ADL/mobility score at discharge and the quartiles of each rehabilitation services units in Table 12. In the OT model, there were significant positive associations between the log odds of community discharge for patients who received OT and ADL score, and that association depended on the quartiles of the OT units received. ($\hat{\beta}$= 0.26 – 0.28; *SE*= 0.01; 95% CIs [0.24, 0.31]; *p*-value<0.001). In other words, for each one-unit increase in the ADL score at discharge, patients with higher ADL scores at discharge had 0.26, 0.27, and 0.28 increase in the log odds of community discharge when they receive 5, 3, or 2 OT units, respectively. Similarly, in the PT model There were significant positive associations between the log odds of community discharge for patients who received PT and mobility score, and that association depended on the quartiles of the PT units received. ($\hat{\beta}$= 0.27 – 0.30; *SE*= 0.01; 95% CIs [0.24, 0.33]; *p*-value<0.0001). Meaning that for each one-unit increase in the mobility score at discharge, patients with higher mobility scores at discharge had 0.27, 0.28, and 0.30 increase in the log odds of community discharge when they receive 6, 4, and 2 PT units, respectively. Using patients who received a total of 5 OT units as the reference group, patients who received a total of 2 OT units had a 0.02 increase in the log odds of community discharge ($\hat{\beta}$= 0.02; *SE*= 0.01; *p-value*<0.001) (Table 13). Likewise in the PT model, using patients who received a total of 6 PT units as the reference group, patients who received a total of 2 PT units had a 0.03 increase in the log odds of community discharge ($\hat{\beta}$= 0.03; *SE*= 0.01; *p-value*<0.0001). Overall, results from tables 4 to 6 indicated that the magnitude of the OT/PT utilization effect diminished as ADL/mobility scores increased. Refer to Figures 7-16 for illustrations of the moderation models. Specifically, Figures 7 –12 visualize the probability and

pairwise comparison (ORs) for community discharge, Figures 13 and 14 illustrate the moderation model (OR), while Figures 15 and 16 present the moderation model and probability of community discharge.

Table 12. Results of the interaction between each quartile of Rehabilitation utilization units and discharge ADL/mobility score and their estimates log odds of community discharge.

Rehabilitation Utilization Quartiles-by-Discharge ADL/Mobility Score	Beta coefficients	Standard error (SE)	95% CI
2 OT Units-by-Discharge ADL Score	0.28	0.01	[0.26, 0.31]
3 OT Units-by-Discharge ADL Score	0.27	0.01	[0.25, 0.30]
5 OT Units-by-Discharge ADL Score	0.26	0.01	[0.24, 0.28]
2 PT Units-by-Discharge Mobility Score	0.30	0.01	[0.28, 0.33]
4 PT Units-by-Discharge Mobility Score	0.28	0.01	[0.26, 0.31]
6 PT Units-by-Discharge Mobility Score	0.27	0.01	[0.24, 0.29]

Note: OT units: based on quartiles of the total number of OT units; Quartiles: 25% = 2, 50%= 3, and 75%= 5 are used as reference points; PT units: based on quartiles of the total number of PT units; Quartiles: 25% = 2, 50%= 4, and 75%= 6 are used as reference points.

Table 13. Results of the interaction between different quartiles of each rehabilitation utilization unit (contrast) and discharge ADL/Mobility Score and their estimates log odds of community discharge.

	Beta coefficients	Standard error (SE)	p-value
2 OT Units – 3 OT Units	0.01	0.002	<.001
2 OT Units – 5 OT Units	0.02	0.01	<.001
3 OT Units – 5 OT Units	0.02	0.004	<.001
2 PT Units – 4 PT Units	0.02	0.004	<.0001
2 PT Units – 6 PT Units	0.03	0.01	<.0001
4 PT Units – 6 PT Units	0.02	0.004	<.0001

Note: Contrasts are based on quartiles of the total number of service units; OT: Occupational Therapy; PT: Physical therapy.

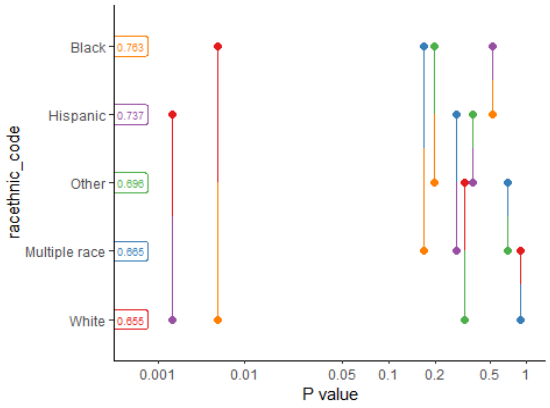

Figure 7.

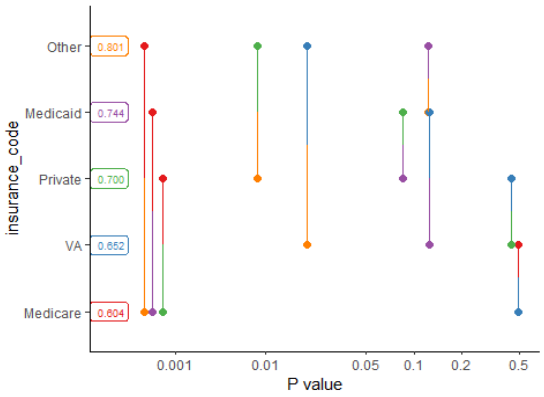

Figure 8.

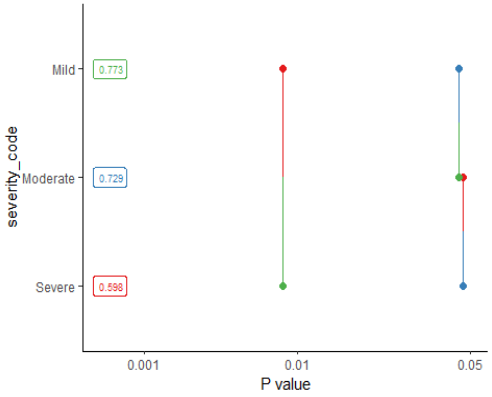

Figure 9.

Note: OT Model graphs. Graphs illustrating the estimated probabilities and odd ratios of community discharge following OT services. X-Axis: in all figures represents the *p*-value; Y-Axis: Probability of each group, arranged from smallest (at the bottom) to largest (at the top); Colored lines: Pairwise Comparisons (odds ratios). In Figure 7. using Black individuals as the reference group (probability= 0.76), non-Hispanic White individuals (probability= 0.65) were 0.59 times less likely to be discharged to community (OR=0.59, 95% CI [0.41, 0.86], *p*-value= 0.01). In Figure 8. Using patients with Medicare insurance as the reference group (probability= 0.60), patients with private insurance (probability= 0.70) were 1.53 times more likely to be discharged to the community (OT: OR= 1.53, 95% CI [1.20, 1.95], $p<0.001$).

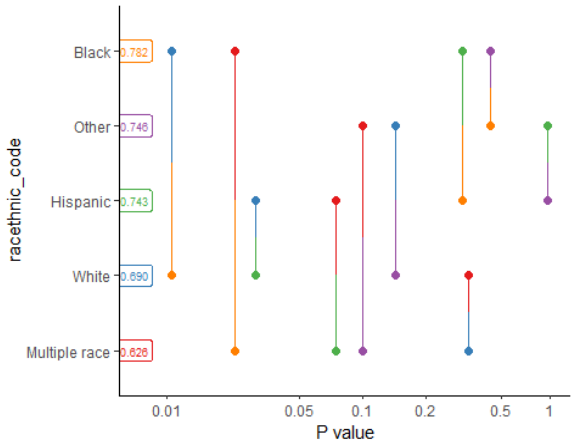

Figure 10.

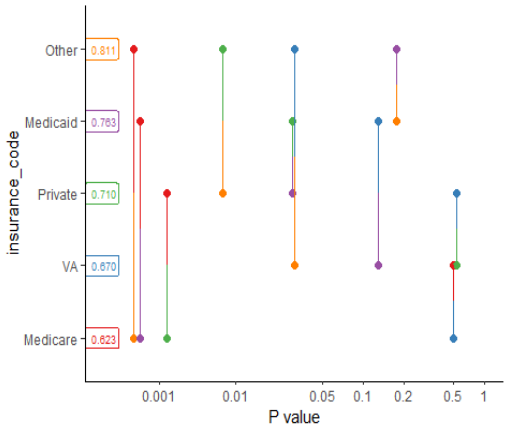

Figure 11.

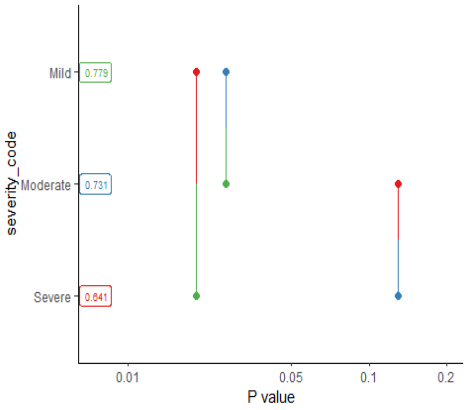

Figure 12.

Note: PT Model graphs. Graphs illustrating the estimated probabilities and odd ratios of community discharge following PT services. X-Axis: in all figures represents the *p*-value; Y-Axis: Probability of each group, arranged from smallest (at the bottom) to largest (at the top); Colored lines: Pairwise Comparisons (odds ratios). In Figure 10. using Black individuals as the reference group (probability= 0.78), non-Hispanic White individuals (probability= 0.69) were 0.62 times less likely to be discharged to community (OR=0.62, 95% CI [0.43, 0.90], *p*-value= 0.01). In Figure 11. Using patients with Medicare insurance as the reference group (probability= 0.62), patients with private insurance (probability= 0.71) were 1.48 times more likely to be discharged to the community (OR= 1.48, 95% CI [1.20, 1.95], *p*-value= 0.001).

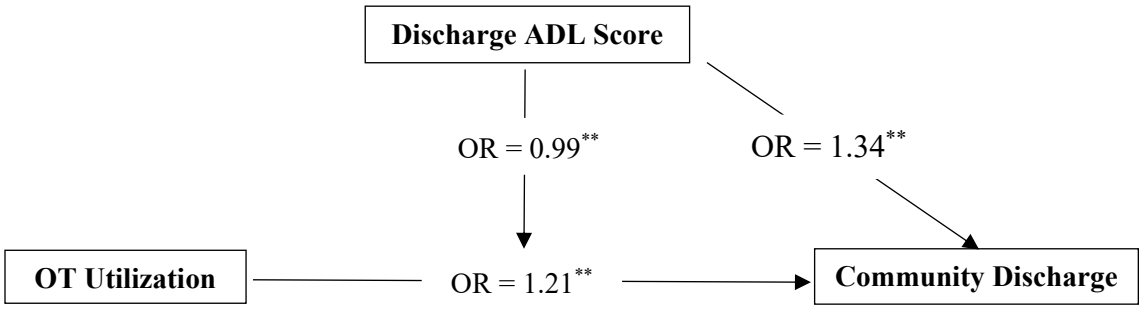

Figure.13 Illustration of occupational therapy (OT) moderation model. Diagram illustrating the moderating effect of discharge activities of daily living (ADL) score on the relationship between OT utilization and the likelihood of discharge to the community. OR = odds ratios; all estimates adjusted for age, sex, race/ethnicity, presence of significant other, insurance type, TBI severity, comorbidity burden, community density, and length of stay; ** = $p<0.001$. Discharge ADL score has a significant moderating effect of on the relationship between OT utilization and the likelihood of discharge to the community.

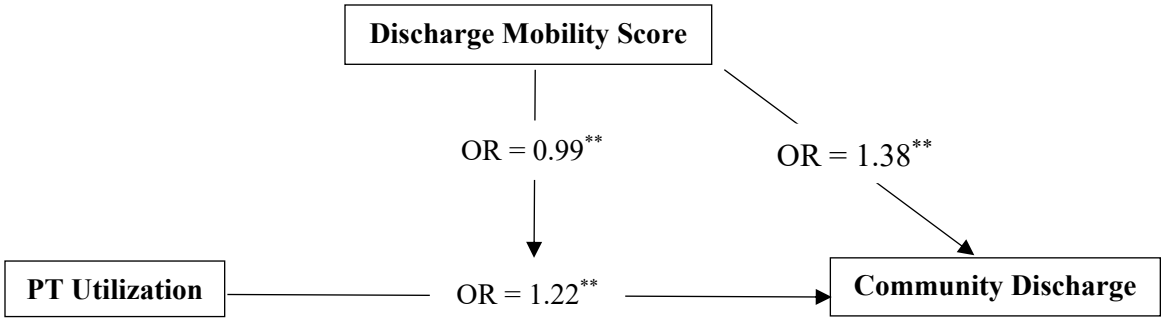

Figure.14 Illustration of physical therapy (PT) moderation model. Diagram illustrating the moderating effect of discharge mobility score on the relationship between PT utilization and the likelihood of discharge to the community. OR = odds ratios; all estimates adjusted for age, sex, race/ethnicity, presence of significant other, insurance type, TBI severity, comorbidity burden, community density, and length of stay; ** = p<0.001. Discharge mobility score has a significant moderating effect of on the relationship between PT utilization and the likelihood of discharge to the community.

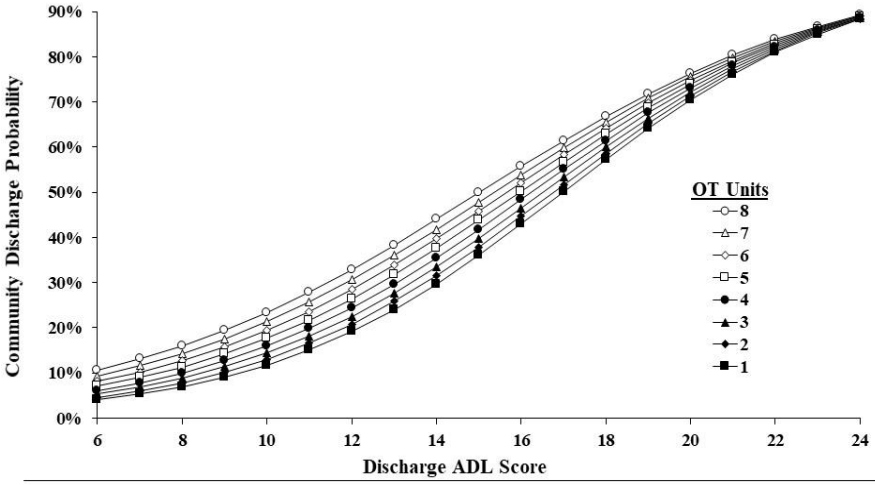

Figure.15 Illustration of occupational therapy (OT) moderation model. Diagram illustrating the moderating effect of discharge ADL score on the relationship between OT utilization and the probability of discharge to the community; all estimates adjusted for age, sex, race/ethnicity, presence of significant other, insurance type, TBI severity, comorbidity burden, community density, and length of stay. Patients had a greater probability of being discharged to the community if they had a higher ADL discharge score and encountered more OT units.

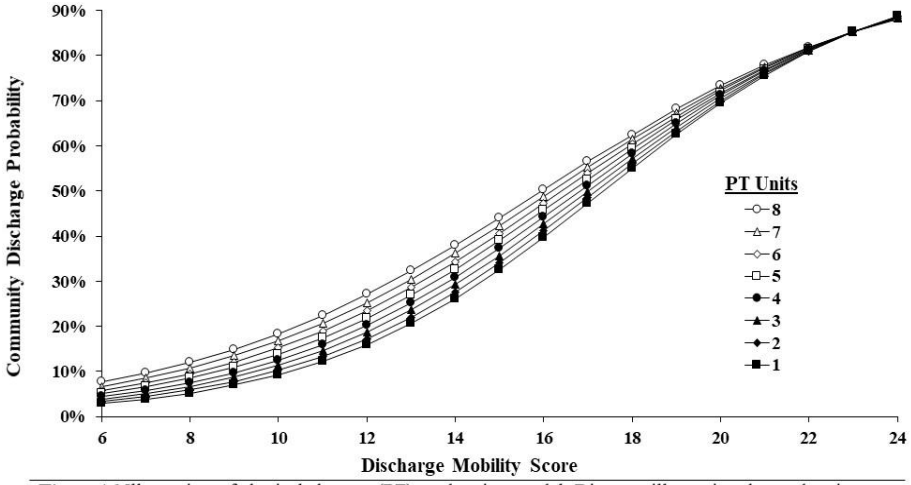

Figure.16 Illustration of physical therapy (PT) moderation model. Diagram illustrating the moderating effect of discharge mobility score on the relationship between PT utilization and the probability of discharge to the community; all estimates adjusted for age, sex, race/ethnicity, presence of significant other, insurance type, TBI severity; comorbidity burden, community density; and length of stay. Patients had a greater probability of being discharged to the community if they had a higher mobility discharge score and encountered more PT units.

DISCUSSION

This study represents the first investigation on whether ADL/mobility performance scores at discharge moderate the relationships between acute care OT/PT utilization and community discharge among adults with TBI. *Greater* OT/PT utilization was associated with 1.21 to 1.22 times *increased* odds of being discharged to the community, respectively. Additionally, a *higher* ADL/mobility performance score at discharge was independently associated with 1.34 to 1.38 times *greater* odds of community discharge, respectively. Subsequently, the small, but statistically significant negative interaction terms in both models indicated that the magnitude of the OT/PT utilization effect diminished as ADL/mobility scores increased (ORs= 0.99, 95% CIs 0.98, 1.00]). These results offer valuable insights for future research, particularly in exploring the interaction between the amount of acute care OT/PT services utilization, discharge ADL/mobility performance, and their impact on community discharge.

It has been proposed that the utilization of acute care OT/PT services increases the likelihood of a safe community discharge, depending on patients' functional or physical performance at discharge. Our results are consistent with previous research indicating that greater OT/PT utilization is associated with an increased likelihood of community discharge (O'Brien & Zhang, 2018; Roberts et al., 2016; Thorpe et al., 2018). Our findings align with prior studies reporting that a higher ADL/mobility performance score at discharge is associated with an increased likelihood of community discharge (Horn et al., 2015; Oyesanya, 2020). However, we also found that the relationship between service utilization and discharge setting varies across discharge ADL/mobility scores. Meaning that the magnitude of the OT/PT utilization effect diminished as ADL/mobility scores increased. In our study, the observed negative statistically significant influence of ADL/mobility scores at discharge between rehabilitation services utilization and community discharge may be attributed to patients' cognitive, affective, or behavioral sequalae of TBI, which are often more disabling than objective ADL/physical performance limitations (Howlett et al., 2022). In our sample, patients with TBI may show a high ADL/mobility performance score at discharge while exhibiting some personality changes such as impulsivity, irritability, or apathy. These changes may contribute to the possibility that the safest discharge plan is still institutional discharge. Future research should investigate the relationship between acute care OT/PT utilization and community discharge, while accounting for patients' cognitive abilities, to better address individuals with TBI prognosis following an acute care setting. Our findings showed that non-Hispanic White patients with TBI were less likely to be discharged to the community relative to both Hispanic and Black patients (OT model White vs. Hispanic (OR= 0.67, 95% CI [0.53, 0.87]), White vs. Black (OR=0.59, 95% CI [0.41, 0.86]); PT model White vs. Hispanic (OR= 0.76, 95% CI [0.61, 0.98]), White vs. Black (OR=0.62, 95% CI

[0.43, 0.90]). This finding is consistent with prior research indicating that non-Hispanic White patients were more likely to experience an institutional discharge (e.g., inpatient rehabilitation facilities) compared to non-ethnic minority patients (Meagher et al., 2015). The effect of ethnic minority status on community discharge may be due to social barriers (e.g., lack of health insurance, lack of transportation, or geographic region) (Bowman et al., 2007; Jacobs et al., 2006). Thus, future research should investigate the impact of ethnic minority status on discharge disposition to better understand potential barriers to safe discharge planning and access to post-acute care (PAC) settings if necessary.

Our findings revealed a negative association between a patient's age and their likelihood of community discharge (ORs=0.98, 95% CIs [0.97, 0.99]). This finding aligns with previous studies indicating that increased age was associated with institutional discharge in patients with TBI (Zarshenas et al., 2019). Older patients in our sample may represent patients with serious premorbid conditions who have demonstrated poor functional/physical outcomes at the time of discharge (Pritchard et al., 2020). As a result, these patients may require further inpatient services to continue improving their independence in everyday activities and mobility prior to discharge to the community. In our study, older patients may have not fully recovered during their acute care stay, making institutional discharge the most medically appropriate plan. Also, in our study, older patients may represent patients whose prior living situation was not in the community. More studies on the influence of age on discharge destination are necessary to understand potential disparities in post-acute discharge disposition while accounting for prior living status.

Our findings emphasized a significant association between the presence of a significant other and the likelihood of community discharge. In particular, compared to patients with

significant others, patients with no significant other were less likely to experience community discharge: (OR=0.62, 95% CI [0.53, 0.74]); (OR=0.64, 95% CI [0.55, 0.76]), for OT and PT models, respectively. This finding aligns with previous studies indicating that patients who have caregivers were more likely to discharge home (Rodakowski et al., 2017). The influence of having a significant other on discharge disposition could be related to patients' goals and preferences for post-acute care and treatment (HHS, 2019). More research is needed to accurately describe the effect of significant other status on healthcare utilization across settings and discharge disposition.

Using patients with Medicaid insurance as the reference group, we observed that patients with private insurance had lower odds of being discharged to the community following PT (OR= 0.76, 95% CI [0.59, 0.97]). This finding aligns with a recent study indicating that patients with public insurance were more likely to discharge to the community relative to patients with private insurance (Sorensen et al., 2020). The influence of insurance type on discharge disposition could be related to patients' socioeconomic status which impacts discharge disposition (Saposnik et al., 2008). Hence, future studies are warranted to explore the impact of financial barriers, including insurance types and coverages, on safe discharge planning across various settings and systems.

Our findings elucidated significant differences in community discharge based on TBI severity and comorbidity burdens. Our results indicated that compared to patients with severe TBI and greater comorbidity burdens, patients with mild TBI and lower comorbidity burdens were substantially more likely to discharge to the community ((OT model: Mild vs. Severe TBI OR= 2.28, 95% CI [1.23, 4.23]); (comorbidity burden OR= 0.93, 95% CI [0.90, 0.96])); ((PT model: Mild vs. Severe TBI OR= 1.97, 95% CI [1.11, 3.50]); (comorbidity burden OR=0.91, 95% CI [0.88, 0.94])). These findings are consistent with prior research indicating that patients

with greater TBI injury severity and comorbidity burden were less likely to discharge to the community relative to patients with lesser TBI injury severity and comorbidity burden (Lu et al., 2022; Sastry et al., 2022). In our sample, patients with TBI who have a greater comorbidity burden may be more likely to have medical complications such as paroxysmal sympathetic hyperactivity that may pose a barrier to safe community discharge (Deshpande et al., 2017; Mathew et al., 2016; Mez et al., 2017). Future research should examine the influence of TBI severity level and comorbidity burden on community discharge across different medical settings.

Our study revealed a significant negative relationship between length of stay in acute care and the likelihood of community discharge (ORs = 0.86, 95% CIs [0.84, 0.88]). This finding aligns with previous literature indicating that patients with longer lengths of stay were less likely to discharge to the community relative to patients with shorter stays (Oyesanya, 2020; Oyesanya, Harris, Yang, et al., 2021). The influence of length of stay on discharge disposition could be related to patients' functional and physical status, impacting community discharge. Patients with longer lengths of stay may have greater medical complications that may pose a barrier to community discharge (Deshpande et al., 2017; Mez et al., 2017). Thus, future studies should examine the influence of patients' lengths of stay and accompanied medical complications on the likelihood of community discharge.

Study Limitations

This study is subject to a few limitations. Firstly, the reliance on EHR data introduces the possibility of missing information, misclassifications, and coding and reporting errors. Additionally, our investigation was confined to 14 hospitals within a single large health system, which may limit the generalizability of our findings to other health systems. It is crucial for future research to replicate our findings in diverse health systems to assess the applicability of

our results to geographically varied patients with TBI. Our dataset had no information about prior living situation; thus, future research should explore the influence of patients' prior living situation on discharge location. Additionally, we did not include cognitive assessment data in our analyses. Standardized cognitive assessments are often not administered to all patients in acute care settings or are not recorded in standard electronic flow sheets. Future studies should examine the influence of patients' cognitive status, if available, on patients' discharge disposition. Our dataset also had no information about prior functional status or home health OT/PT. Future research should explore the influence of patients' prior functional status, and home health OT/PT on discharge ADL/mobility score and specific discharge location. Our study did not examine specific discharge destinations, such as Inpatient Rehabilitation Facility (IRF) versus skilled nursing facility; instead, discharge disposition was categorized broadly into community versus institutional. Future research should explore the association between OT/PT utilization and specific discharge destinations to provide a more detailed understanding of the determinants of discharge location among patients hospitalized with TBI in acute care settings.

CONCLUSION

We examined whether ADL/mobility performance score at discharge moderated the relationship between acute care OT/PT utilization and discharge to the community among adults with TBI. Both ADL and mobility performance scores at discharge moderated the relationship between OT/PT utilization and community discharge. *Higher* OT/PT utilization was associated with *increased* odds of being discharged to the community and *higher* ADL/mobility performance score at discharge was independently associated with *greater* odds of community discharge. The observed positive statistically significant effects of OT/PT utilization simply decreased with increasing discharge ADL/mobility scores. Further research is warranted to

determine the generalizability of our findings, evaluate the impact of patients' prior health and cognitive status, and other sociodemographic factors (e.g., age, ethnicity, insurance type, and significant other status) on the relationship between OT/PT utilization and community discharge. Findings of this study can inform occupational and physical therapists' efforts aimed at ensuring a safe community discharge for patients with TBI.

CHAPTER FOUR: THE IMPACT OF ACUTE CARE OCCUPATIONAL AND PHYSICAL THERAPY SERVICES ON UNPLANNED HOSPITAL READMISSION AMONG INDIVIDUALS WITH TRAUMATIC BRAIN INJURY

OVERVIEW

Objective: To investigate whether discharge functional and/or mobility status are associated with unplanned hospital readmission among individuals hospitalized with traumatic brain injury (TBI).

Setting: 14 acute care hospitals in the state of Colorado.

Participants: 769 adults hospitalized with TBI between January 2018 and December 2021.

Design: Secondary analysis of de-identified electronic health record (EHR) data. We performed logistic regression to calculate odds ratios (ORs) for the likelihood of 90-day readmission among those who received occupational and physical therapy services during their acute care stay.

Main Measures: Functional and mobility status at discharge, and readmission status.

Results: Neither discharge functional nor mobility scores were associated with readmission (*p*-values= 0.14 – 0.17). Two covariates, related to insurance and TBI severity, were statistically significant. Compared to patients with public insurance, patients with managed care were 0.52 times less likely to be readmitted (OR= 0.52, 95% CI [0.30, 0.88]). In comparison to patients with moderate TBI, patients with mild TBI were 0.53 times less likely to be readmitted (OR = 0.53, 95% CI [0.29, 0.96]). The estimated probability of readmission was highest for patients with public insurance (0.18), and patients with severe TBI (0.22), and was lowest for patients with managed care insurance and mild TBI (0.10).

Conclusion: Further research is needed to determine whether discharge functional and mobility scores were too limited to capture the benefits of acute care rehabilitation services in reducing 90-day readmission risk in hospitalized patients with TBI. Other individual-level factors such as insurance types and TBI severity levels demonstrated clear relationships with readmission status. These results have substantial implications for occupational and physical therapists, offering insights into patient factors that may contribute to a heightened risk of readmission. Early identification of high-risk patients can empower occupational and physical therapists to offer tailored interventions, resources, and support, thereby mitigating the risk of readmission and improving overall patient outcomes.

The Impact of Acute Care Occupational and Physical Therapy Services on Unplanned Hospital Readmission Among Individuals with Traumatic Brain Injury

Introduction

Hospital readmissions, defined as unplanned inpatient admissions to an acute care hospital within 30 days of discharge from a previous hospitalization (CMS, 2016), constitute a global challenge, posing financial, social, and medical burdens (Atzema et al., 2018). In the United States, hospital readmissions are common, expensive, and often avoidable among Medicare beneficiaries (MedPAC, 2018). The Medicare Payment Advisory Commission (MedPAC) projected that between 17% and 20% of Medicare beneficiaries discharged from hospitals were readmitted within 30 days (MedPAC, 2018). Unfortunately, approximately 75% of these readmissions were likely preventable, costing Medicare $17 billion annually (MedPAC, 2018).

Readmission is prevalent among individuals with chronic illnesses or injuries, and is associated with higher healthcare expenses and lower quality of care (Jencks et al., 2009). Notably, readmission rates after TBI contribute considerably to these costs, making lowering readmission rates a universal goal (Canner et al., 2016). A 2018 report from the Department of Health and Human Services (HHS), disclosed that there was a readmission rate of 28% for individuals with TBI within their first year following discharge, with minimal subsequent decline in the following five years, averaging 22-23.4% (Zatzick et al., 2017). While some hospital readmissions are scheduled for elective procedures (i.e., cranioplasty, orthopedic surgery, or other reconstructive surgeries), other readmissions are unplanned and may disrupt the intended

course of rehabilitation, thereby hindering neurological and functional progress (Hammond et al., 2015; Hoffman et al., 2020).

In the U.S., several programs and quality measures have been established to encourage hospitals to improve communication and care coordination. The goal of these programs are to better engage patients and caregivers in discharge plans and, in turn, reduce avoidable readmissions (Charlayne Van et al., 2016; CMS, 2016). Lowering readmission rates leads to better outcomes for the general population, through enhancing quality of care, improving overall health, and decreasing financial burdens for patients, caregivers, providers, and payers (Hoffman et al., 2020; Middleton, Graham, et al., 2018; Mitsutake et al., 2020). Acute care rehabilitation services may play a key role in helping providers reduce unnecessary readmissions.

The goal of acute care rehabilitation services is to improve or at least maintain the functional capacity (i.e., self-care and mobility) of hospitalized patients. Better functioning is associated with greater independence and lower hospitalization risk (Arnold et al., 2021; Johnson et al., 2021). However, limited knowledge exists about the relationship between the Activity Measure for Post-Acute Care's (AM-PAC^{TM}) "6-Clicks" functional /mobility scores at hospital discharge and unplanned readmission in adults with TBI. Confirming the association between functional /mobility scores at hospital discharge and unplanned readmission in adults with TBI will inform more effective strategies to reduce readmission rates. This will allow healthcare providers to personalize intervention and post-discharge follow-up plans to address patients' needs. Therefore, we hypothesized that patients with high AM-PAC^{TM} scores (i.e., better functioning status) at discharge are less likely to be readmitted to acute care within 90 days, after adjusting for other patient-level factors.

METHODS

Participants and procedure

This was a retrospective cross-sectional study of de-identified electronic health record (EHR) data. EHR data was collected from 14 trauma centers, levels I to IV, within a single large health system in the state of Colorado. The study included EHR data from 66,830 patients admitted and discharged between January 2018 and December 2021. Inclusion criteria were an adult (aged ≥ 18 years), admitted to the hospital with a TBI diagnosis based on International Classification of Diseases (ICD-10) codes for admission, and had at least one OT/PT evaluation/treatment session. We excluded patients who did not survive the hospitalization or were missing data on key variables of interest. These data were de-identified, organized, and supported by the Health Data Compass Data Warehouse project (healthdatacompass.org). After applying the inclusion and exclusion criteria, the final sample consisted of 769 adults (Figure 17). Although we excluded subjects with missing data, close examination of patients with missing data revealed no systematic differences in the independent or dependent variables compared to patients without missing data. A signed data-use agreement was in-place, and the study was approved by Colorado State University Institutional Review Board. The *Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)* reporting guidelines were applied to this study (von Elm et al., 2014). See (appendix A) for more information about *STROBE* statements.

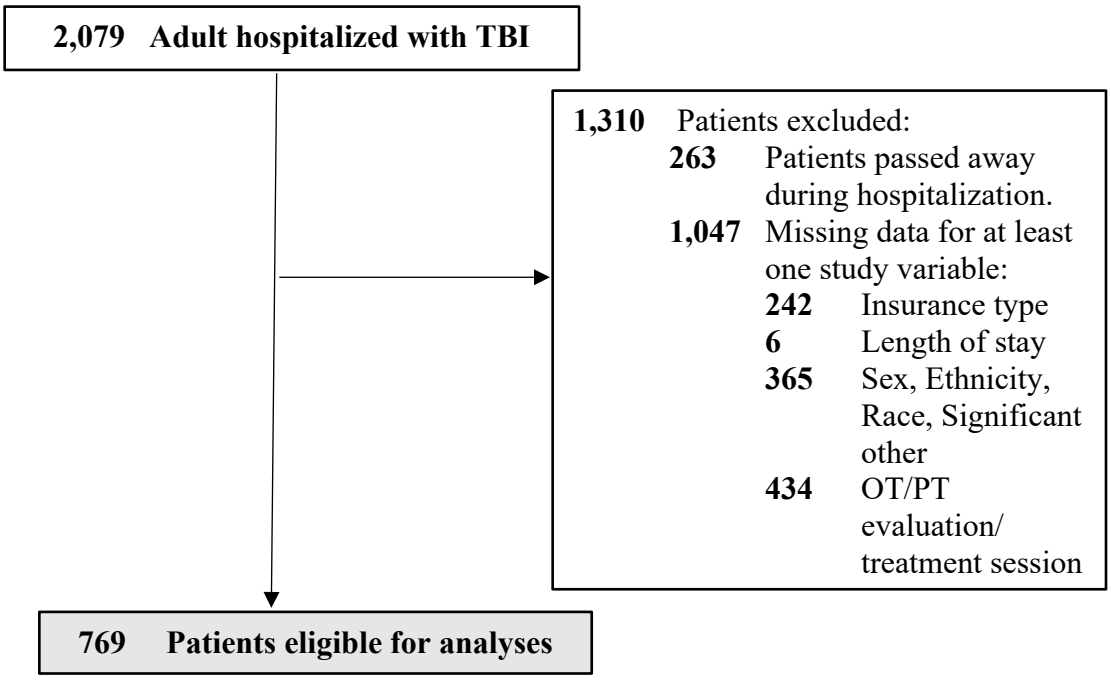

Figure 17. Cohort Selection Diagram

Measures

Functional/mobility status at discharge

Patients functional/mobility status at discharge were measured using the AM-PAC™ "6-Clicks" inpatient short form scores in both daily activity and basic mobility domains (Jette et al., 2014). OT practitioners rate the following activities of daily living (ADLs) according to level of assistance needed on a scale of 1 (“total”) to 4 (“none”): upper body dressing, lower body dressing, bathing, toileting, grooming, and eating (Jette et al., 2014). PT practitioners rate the following activities of physical performance according to level of assistance needed on a scale of 1 (“total”) to 4 (“none”): bed mobility, sit to stand, supine to sit, seated transfers, ambulation, and ascending stairs (Jette et al., 2014). The AM-PAC "6-Clicks" has very high internal consistency among OT and PT practitioners: Cronbach’s alpha = 0.91and 0.96 for ADL and mobility assessments, respectively (Jette et al., 2014). The AM-PAC "6-Clicks" scores are standardized (Jette et al., 2014), with higher scores indicating greater ADL performance (range =

17.07 – 57.54), as well as greater basic mobility abilities (range = 23.55 – 61.14) (Jette et al., 2014).

Readmission status

Patient's 90-day readmission status was defined dichotomously (yes/no) by whether the patient had encountered unplanned readmission within 90 days following discharge from a previous acute care stay.

Covariates

We included person-level factors such as age (years); sex (female/male); ethnicity (Hispanic, and non-Hispanic); race (White, Black, and Other); presence of a significant other (yes/no); insurance type (e.g., Public [e.g., Medicare, Colorado Medicaid, Out of State Medicaid, Indigent Care, and Tricare], Managed Care [e.g., Managed Medicare, Managed Medicaid, Managed Care, Commercial, CU - UA NET, UCHEALTH EMPLOYEE PLAN, and Fi], and Others [e.g., Special Accounts, Self-Pay, and Workers Comp]); length of stay (days); comorbidity burden (using Functionally relevant TBI Comorbidity Index [Fx-TBI-CI] (Kumar et al., 2022)), and TBI severity (e.g., Mild; Moderate; and Severe (Defense and Veterans Brain Injury Center, 2015)) as covariates. The Fx-TBI-CI is a method used to categorize patients' with TBI comorbidities based on the International Classification of Diseases (ICD-10) diagnosis codes obtained from hospital administrative data (Kumar et al., 2022). The Fx-TBI-CI was calibrated based on the function of individuals with TBI receiving inpatient care (Kumar et al., 2022). We constructed a weighted summary index according to Kumar et al. (2022) to evaluate comorbidity burden. We applied the Defense and Veterans Brain Injury Center (DVBIC) ICD-10 classification structure to the codes we obtained from the EHR to classify TBI severity: mild, moderate, and severe (Defense and Veterans Brain Injury Center, 2015).

Data analysis

Descriptive statistics (e.g., means, standard deviations, percentages) were computed for the entire sample and stratified by readmission status. We used bivariate analyses to examine unadjusted differences in patient characteristics between readmission groups: Chi-square, independent t-tests, and ANOVAs. Specifically, Chi-square and ANOVA analyses were conducted to assess the association between dichotomous and categorical variables (i.e., three or more levels), respectively, and the dependent variable (e.g., readmission status [yes/no]). Independent t-tests were utilized to examine the association between all continuous variables and the dependent variable (e.g., readmission status [yes/no]). Logistic regression was performed with 90-day unplanned readmission status as the dependent variable and patients functional (i.e., ADL) or physical (i.e., mobility) status at discharge as the main predictors of interest. Estimates (e.g., odds ratios, confidence intervals) were adjusted for age, sex, ethnicity, race, presence of a significant other, insurance type, length of stay, comorbidity burden, and TBI severity levels. Statistical significance was evaluated at $\alpha = .05$ for all parameter estimates. All analyses were performed using R (Version 4.3.1) (R Core Team, 2023).

RESULTS

Among the 769 patients included in the study, only (12.5%) were readmitted (Table 14). The mean patient age was 60.6 years (*SD*=17.6). Most of the sample were males (61%), White (83%), non-Hispanic (89%), and had no significant other (51 %). Patients with public health insurance represented the largest insurance group (59%), followed by those with managed care (34%), and other insurance (7%). Most patients experienced moderate TBI severity (73%). Results of the Chi-square and ANOVA analyses indicated statistically significant differences in readmission with respect to patients' sex ($\chi^2(1) = 4.36$, *p*-value= 0.04), and TBI severity groups

(F(1.2, 169.0)=5.5, *p*-value= 0.02). Results of bivariate t-test analysis showed that there were statistically significant associations between various discharge mobility scores (t(767)=-0.79, *p*-value=0.01) with readmission status. See Table 14.

Table 14. Sample characteristics with descriptive summaries of Readmission within 90-day.

		Readmission, *n* (%)		
	N (%)	No	Yes	*p*-value
Total	769 (100%)	673 (87.5%)	96 (12.5%)	
Discharge ADL score, in AM-PAC, mean (*SD*)	17.7 (5.1)	17.7 (5.2)	17.7 (4.9)	0.22
Discharge Mobility score, in AM-PAC, mean (*SD*)	18.2 (5.1)	18.1 (5.2)	18.7 (4.5)	**0.01**
Age in years, mean (*SD*)	60.6 (17.4)	60.6 (17.6)	60.6 (15.9)	0.15
Sex				**0.04**
Male	470 (61.1%)	402 (85.5%)	68 (14.5%)	
Female	299 (38.9%)	271 (90.6%)	28 (9.4%)	
Significant other				0.71
Yes	374 (48.6%)	329 (88.0%)	45 (12.0%)	
No	395 (51.4%)	344 (87.1%)	51 (12.9%)	
Ethnicity				0.53
Non-Hispanic	687 (89.3%)	603 (87.8%)	84 (12.2%)	
Hispanic	82 (10.7%)	70 (85.4%)	12 (14.6%)	
Race				0.32
White	636 (82.7%)	561 (88.2%)	75 (11.8%)	
Black	29 (3.8%)	23 (79.3%)	6 (20.7%)	
Other	104 (13.5%)	89 (85.6%)	15 (14.4%)	
Insurance Type				0.13
Public	457 (59.4%)	390 (85.3%)	67 (14.7%)	
Managed Care	258 (33.6%)	237 (91.9%)	21 (8.1%)	
Others	54 (7.0%)	46 (85.2%)	8 (14.8%)	
TBI Severity				**0.02**
Mild	194 (25.2%)	179 (92.3%)	15 (7.7%)	
Moderate	558 (72.6%)	480 (86.0%)	78 (14.0%)	
Severe	17 (2.2%)	14 (82.4%)	3 (17.6%)	
Length of Stay in days, mean (*SD*)	13 (18.1)	13 (18.3)	10.8 (16.3)	0.26
FX-TBI-CI, mean (*SD*)	3.3 (3.9)	3.3 (3.9)	2.7 (3.7)	0.94

Note: SD=standard deviation; AM-PAC = The Activity Measure for Post-Acute Care "6-Clicks"; Daily activity = Occupational Therapy score; Basic mobility = Physical Therapy scores; D/C= hospital discharge; FX-TBI-CI = functionally relevant TBI comorbidity index.

There was not sufficient evidence to suggest that patients ADL and mobility score at discharge were good predictors of readmission (p-values= 0.14 – 0.17) (Table 15). There was evidence to suggest that patients with public insurance were significantly and positively associated with the log odds of readmission ($\hat{\beta}$= 0.66; SE= 0.27; p-value=0.02) relative to patients with managed care insurance. There was evidence to suggest that patients with moderate TBI were significantly and positively associated with the log odds of readmission ($\hat{\beta}$= 0.64; SE= 0.30; p-value=0.04) compared to patients with mild TBI. There was not sufficient evidence to suggest that the other covariates (i.e., age, sex, significant other status, ethnicity, race, length of stay, and comorbidity burden score) were significantly associated with readmission (p-values= 0.07 – 0.95). Table 15 presents the coefficient estimates from the logistic regression analysis.

Table 15. Results of logistic regression analysis for 90-day-readmission.

	Beta coefficients	Standard error (SE)	p-value
Intercept	-2.88	0.82	**<0.001**
Discharge ADL score (AM-PAC)	-0.06	0.04	0.14
Discharge Mobility score (AM-PAC)	0.05	0.04	0.17
Age (years)	-0.0004	0.01	0.95
Sex (ref. = Female)	0.45	0.25	0.07
Significant other (ref.= No)	-0.04	0.24	0.87
Ethnicity (ref. = non-Hispanic)	0.09	0.41	0.82
Race (ref. = White)			
Black	0.80	0.50	0.11
Other	-0.04	0.39	0.91
Insurance Type (ref. = Managed Care)			
Public	0.66	0.27	**0.02**
Other	0.56	0.47	0.23
TBI severity (ref. = Mild)			
Moderate	0.64	0.30	**0.04**
Severe	1.07	0.71	0.13
Length of Stay (days)	-0.01	0.01	0.25
FX-TBI-CI	-0.04	0.03	0.22

Note: Ref. = reference category; AM-PAC = The Activity Measure for Post-Acute Care "6-Clicks"; FX-TBI-CI = functionally relevant TBI comorbidity index.

Probabilities of readmission for each insurance type, and TBI severity group are provided in Table 16. The estimated probability of readmission was highest for patients with public insurance (0.18), followed by other types of insurance (0.17) and was lowest for patients with managed care insurance (0.10). The estimated probability of readmission was highest for patients with severe TBI (0.22), followed by moderate TBI (0.15) and was lowest for patients with mild TBI (0.10).

Table 16. Results of the estimated probability of readmission of significant groups from logistic regression analysis.

	Probabilities	Standard error (SE)	Asymp LCL	Asymp UCL
Insurance Type				
Public	0.18	0.05	0.10	0.29
Managed Care	0.10	0.03	0.05	0.19
Other	0.17	0.07	0.07	0.34
TBI Severity				
Mild	0.09	0.03	0.05	0.16
Moderate	0.15	0.03	0.10	0.24
Severe	0.22	0.12	0.07	0.52

Note: Asymp. LCL = Asymptotic Lower Confidence Limit; Asymp. UCL = Asymptotic Lower Confidence Limit

Although there was not sufficient evidence to suggest that our main predictors of interest (e.g., patients ADL and mobility score at discharge) were good predictors of readmission (*p*-values= 0.14 – 0.17). Several covariates (e.g., insurance type, and TBI severity) were significantly associated with readmission (Table 17). Compared to patients with public insurance, patients with managed care were 0.52 times less likely to be readmitted (OR= 0.52, 95% CI [0.30, 0.88]). In comparison to patients with moderate TBI, patients with mild TBI were

0.53 times less likely to be readmitted (OR = 0.53, 95% CI [0.29, 0.96]). Several other covariates (i.e., age, sex, significant other status, ethnicity, race, length of stay, and comorbidity burden score) were not significantly associated with readmission (*p*-values= 0.07 – 0.95). Figures 2 and 3 illustrate the pairwise comparisons between insurance type sub-groups and TBI-severity sub-groups for the odds of readmission.

Table 17. Results of pairwise comparisons (odds ratios) for readmission.

	OR	Standard error (SE)	95% CI	*p*-value
Insurance Type				
Managed Care / Other	0.57	0.27	[0.23, 1.44]	0.23
Managed Care / Public	0.52	0.14	**[0.30, 0.88]**	**0.02**
Other / Public	0.90	0.39	[0.39, 2.10]	0.81
TBI Severity				
Mild / Moderate	0.53	0.16	**[0.29, 0.96]**	**0.04**
Mild / Severe	0.34	0.24	[0.08, 1.38]	0.13
Moderate / Severe	0.65	0.43	[0.17, 2.41]	0.52

Note: OR = Odd ratio; CI= Confidence Intervals; The reference groups in all pairwise comparisons are the groups listed after the forward slash.

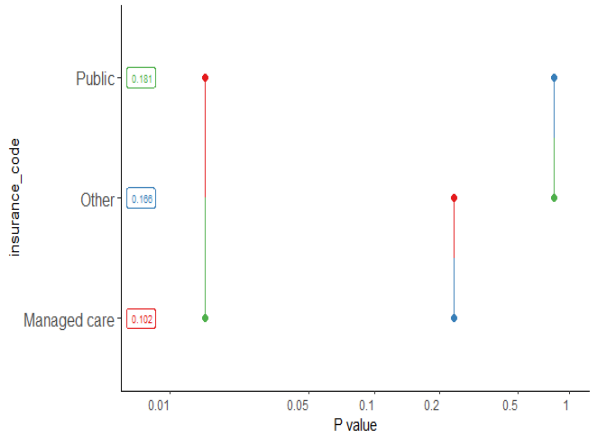

Figure 17.

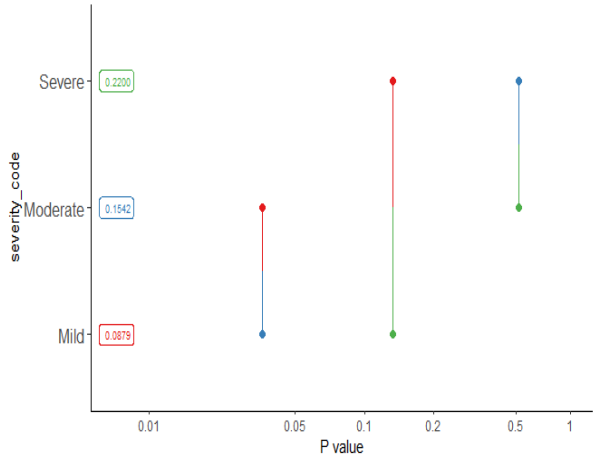

Figure 18.

Note: Readmission graphs. Graphs illustrating the estimated probabilities and odd ratios of readmission following rehabilitation services. X-Axis: in all figures represents the *p*-value; Y-Axis: Probability of each group, arranged from smallest (at the bottom) to largest (at the top); Colored lines: Pairwise Comparisons (odds ratios). In Figure 17. Compared to patients with public insurance (probability= 0.18), patients with managed care (probability= 0.10) were 0.52 times less likely to be readmitted (OR= 0.52, 95% CI [0.30, 0.88], *p*-value= 0.02). In Figure 18. Relative to patients with moderate TBI (probability= 0.15), patients with mild TBI (probability= 0.09) were 0.53 times less likely to be readmitted (OR = 0.53, 95% CI [0.29, 0.96], *p*-value= 0.04).

DISCUSSION

This study is among the first to examine the relationship between the AM-PAC's "6-Clicks" daily activity and basic mobility scores at discharge and unplanned acute care readmission in adults with TBI. While two co-variates were significantly associated with readmission risk, it is noteworthy that neither daily activity nor basic mobility scores at discharge were associated with unplanned hospital readmission in adults with TBI (*p*-values= 0.14 – 0.17).

Patients with managed care insurance type were associated with lesser odds of being readmitted to acute care hospital compared to their public health insurance counterparts (OR= 0.52, 95% CI [0.30, 0.88], *p*-value= 0.02). Patients' TBI severity levels were also a significant predictor of readmission. Patients experiencing mild TBI severity were associated with reduced odds of being readmitted to acute care hospital compared to those with moderate TBI severity (OR = 0.53, 95% CI [0.29, 0.96], *p*-value= 0.04). While this study sheds light on certain aspects of acute care readmission among individuals with TBI, additional research is warranted to uncover the nuanced and modifiable factors influencing readmission and to refine strategies for reducing readmissions in this vulnerable population.

Our study did not yield conclusive evidence to support our initial hypothesis regarding the association between high AM-PAC^{TM} scores at discharge and a reduced likelihood of 90-day readmission to acute care among individuals with TBI (*p*-values= 0.14 – 0.17). These results are contrary to prior research conducted on different diagnoses, which indicated that higher AM-PAC^{TM} scores were associated with lower odds of readmission (Arnold et al., 2021; Johnson et al., 2021). While these findings present a deviation from our initial expectations, they offer a valuable foundation for future research directions. In our sample, the mean length of stay for patients was 13 days, which may be too short to capture meaningful changes in discharge AM-

PAC scores for patients with TBI. Exploring additional patient-level factors and their implications on readmission status may provide a more comprehensive understanding of the complexities involved in post-TBI care and could inform targeted interventions to reduce readmission rates.

Our findings indicated that patients with managed care were less likely to be readmitted compared to those with public insurance (OR= 0.52, 95% CI [0.30, 0.88], *p*-value= 0.02). This result is consistent with previous studies that have shown lower readmission rates among patients with managed care compared to patients with public insurance (Agarwal et al., 2021; Jacobs & Basu, 2020; Jung et al., 2020). The influence of insurance types could be related to patients' socioeconomic status which impacts hospital readmission (Li et al., 2018; Lu et al., 2022). Thus, future studies are needed to delve deeper into the influence of financial barriers, such as insurance types and coverages, on unplanned hospital readmission across various healthcare settings and systems. A more comprehensive understanding of these factors can inform the development of targeted policies aimed at reducing readmission rates and enhancing the quality of care for patients with TBI.

Patients with mild TBI severity were less likely to be readmitted than their moderate TBI counterparts (OR = 0.53, 95% CI [0.29, 0.96], *p*-value= 0.04). This finding reinforces the consensus in previous research, indicating that more severe TBI cases are more likely to be readmitted (Hoffman et al., 2020; Li et al., 2018; Saverino et al., 2016; Tran et al., 2017). Throughout the literature, TBI severity and associated comorbidities were examined, and showed that patients with greater severity and comorbidities have an increased likelihood of readmission (Brenner et al., 2020; Hoffman et al., 2020; Karr et al., 2021; Lu et al., 2022; Sastry et al., 2022; Zatzick et al., 2017). To enhance the robustness and generalizability of these findings, future

studies should aim to replicate these findings across various healthcare systems. Such endeavors will contribute to a deeper understanding of whether TBI severity levels and pre-existing comorbidities impact unplanned hospital readmissions. Confirming the association between TBI severity and pre-existing comorbidities and unplanned hospital readmissions will inform more effective strategies to reduce readmission rates. Understanding that patients with greater TBI severity and comorbidities are at a higher risk of readmission will allow healthcare providers to personalize intervention and post-discharge follow-up plans to address patients' needs. This personalized approach not only enhances the efficiency of readmission prevention strategies but also improves overall quality of care for individuals with TBI.

Our study's findings revealed a lack of statistically significant relationships between patients' gender, ethnicity, and the presence of a significant other and their readmission status (p-values= 0.07 – 0.95). These results deviate from prior research showing associations between these demographic factors and readmission risk. Previous research reported that males have greater likelihood of being readmitted over females (Brown et al., 2021; Ho et al., 2019; Li et al., 2018; Saverino et al., 2016); Black patients have greater likelihood of being readmitted over Hispanic and non-Hispanic White patients (Hsia. RY et al., 2018); patients with significant others are less likely to experience unplanned readmissions (Cakir et al., 2017; Lin et al., 2022; Schultz et al., 2022). A plausible explanation for these inconsistent findings may be related to the relatively small sample sizes across specific subgroups within these demographic variables. More research is necessary to confirm the relationships between these and other sociodemographic variables and readmission risk. Such investigations will provide valuable insights into the nuanced relationship between these factors and acute care readmissions.

Study Limitations

This study has a few limitations. First, the use of EHR data may involve missing information, misclassifications, coding and reporting errors. Further, our study was limited to 14 hospitals within a single large health system and findings may not generalize to other health systems. Future research should replicate findings in different health systems and geographical regions to determine if results translate to geographically diverse patients with TBI. Additionally, our dataset has no information about patients' cognitive abilities because standardized cognitive assessments are often not administered to all patients in acute care settings nor recorded in standard electronic medical record flow sheets. Future studies should examine the influence of patients with TBI cognitive status if available on readmission status following acute care discharge. Furthermore, our dataset has no information about prior health status, nor pre-hospital living status. Future research should explore the influence of patients' prior health status, and pre-hospital living status on readmission status.

CONCLUSION

We examined the relationship between the AM-PAC's "6-Clicks" daily activity and basic mobility scores at discharge and unplanned 90-day readmission in adults with TBI in acute care settings. Discharge AM-PAC scores were not associated with 90-day readmission. Among several covariates, including sex, ethnicity, race, significant other status, insurance type, and TBI severity; only insurance type and TBI severity level were significantly associated with 90-day readmission. Further research is essential to determine the generalizability of our findings beyond the single health system utilized in this study. These results provide valuable insights for occupational and physical therapists, enabling them to identify patient factors that may

contribute to a higher risk of readmission among individuals hospitalized with TBI. By proactively identifying high-risk patients, therapists can offer the necessary resources, targeted care, and support to mitigate readmission risk, ultimately enhancing patient outcomes and reducing healthcare costs.

CHAPTER FIVE: CONCLUSION

The purpose of this dissertation was to conduct various research studies aimed at gaining a comprehensive understanding of the barriers and facilitators of equitable access to and timing of rehabilitation services, community discharge, and unplanned 90-day post-discharge hospital readmission among individuals hospitalized with TBI. To achieve this purpose, three studies were conducted, resulting in three manuscripts to be submitted for publication to academic journals. The results of these studies complemented one another and provided a comprehensive picture of the acute care rehabilitation experience of individuals with TBI. In this section of the dissertation, the findings of these three studies are brought together to draw attention to commonalities and to highlight a potential path for future research.

COMMON FINDINGS THROUGHOUT THE THREE STUDIES

In chapter 2, I presented Study One, which used multivariable logistic and Cox regressions (i.e., time-to-event analyses) to calculate odds ratios for the likelihood of receiving OT and PT services, and hazard ratios for the duration to initiation of services among those who received these services. In this study, we found that all community-level SDoH such as education attainment, income, and rurality did not show significant associations with access to or timing of acute rehabilitation services (*p*-values= 0.09 – 0.95).

In chapter 3, Study Two employed multivariable moderation logistic regression models to calculate odds ratios for the likelihood of community discharge among those who utilized OT/PT services depending on patients' functional or physical performance at discharge. This study revealed that both ADL/mobility performance scores at discharge significantly moderated the

relationship between OT/PT utilization and community discharge (ORs= 0.99, 95% CIs [0.98, 1.00]).

In chapter 4, Study Three used logistic regression to calculate odds ratios for the likelihood of 90-day readmission among those who received rehabilitation services (OT/PT) during their acute care stay. This study demonstrated that neither discharge functional nor mobility scores were associated with readmission (*p*-values= 0.14 – 0.17). In the following sections, I will discuss common covariate findings across the three studies, how my dissertation can contribute to the field of occupational and rehabilitation sciences, and directions for future research.

Age

Age was a significant co-variate in both Study One and Study Two. In Study One, our findings revealed a positive association between a patient's age and their access to and timing of OT and PT services in acute care. Specifically, for each one-year increase in age, older patients were 1.02 times more likely to receive rehabilitation services (ORs=1.02, 95% CI [1.01, 1.03]); and were 1.01 times more likely to experience shorter wait times to receive both rehabilitation services relative to their younger counterparts (HRs=1.01, 95% CIs [1.00-1.01]). This finding aligns with previous studies indicating that older patients received rehabilitation services more promptly (Hargreaves et al., 2015; Robards et al., 2019).

In Study Two, our findings revealed a negative association between a patient's age and their likelihood of community discharge. Specifically, for each one-year increase in age, older patients were 0.98 times less likely to be discharged to the community relative to younger patients (ORs=0.98, 95% CIs [0.97, 0.99]). This finding aligns with previous studies indicating

that increased age was associated with institutional discharge in patients with TBI (Zarshenas et al., 2019).

More studies on the influence of age on onset of rehabilitation services and discharge destination are necessary to identify potential differences in accessibility to rehabilitation services and disparities in post-acute discharge disposition while accounting for socioeconomic status, or types of health care insurance, and prior living status.

Significant Other Status

The presence of a significant other was a significant co-variate in both Study One and Study Two. In Study One, our findings showed a significant association between the presence of a significant other and the likelihood of receiving OT services. Compared to patients with a significant other, patients without a significant other were 0.82 times less likely to receive OT (OR= 0.82, 95% CI [0.68, 0.99]). This finding aligns with the prior research indicating that patients who have a significant other (i.e., a spouse or caregiver) are more likely to have better access to healthcare services (Albrecht et al., 2017; Hao et al., 2020; Lin et al., 2022; Owolabi et al., 2023).

In Study Two, we observed a significant association between the presence of a significant other and the likelihood of community discharge. Specifically, individuals without a significant other were 0.62 to 0.64 times less likely to experience community discharge (OT model: OR=0.62, 95% CI [0.53, 0.74]; PT model: OR=0.64, 95% CI [0.55, 0.76]). This finding aligns with previous studies indicating that patients who have caregivers were more likely to discharge home (Rodakowski et al., 2017).

Future research is needed to examine the impact of having social support on access to healthcare services and discharge disposition in different settings and among various

populations. Such investigations can provide a more comprehensive understanding of the multifaceted role of social support in facilitating healthcare access and safe discharge planning, ultimately aiding in the development of more inclusive and effective healthcare strategies.

Race and Ethnicity

Race/ethnicity was a significant co-variate in both Study One and Study Two. In Study One, our findings showed that compared to non-Hispanic White individuals, Black individuals were 0.88 times less likely to experience shorter wait times to receive OT service only (HR=0.88, 95% CI [0.77-0.99]). This result aligns with the existing literature indicating that non-Hispanic White patients are more likely to obtain high quality health care and rehabilitation services relative to other race/ethnicity groups (Albright et al., 2020; Cancel-Tirado et al., 2018; Meagher et al., 2015; Schoenfeld et al., 2019).

In Study Two, our findings showed that White individuals were less likely to be discharged to the community relative to their Hispanic and Black counterparts in both models (OT model White vs. Hispanic (OR= 0.67, 95% CI [0.53, 0.87]), White vs. Black (OR=0.59, 95% CI [0.41, 0.86]); PT model White vs. Hispanic (OR= 0.76, 95% CI [0.61, 0.98]), White vs. Black (OR=0.62, 95% CI [0.43, 0.90]). This finding is consistent with prior research indicating that ethnic minority patients were less likely to experience an institutional discharge (e.g., inpatient rehabilitation) compared to non-Hispanic White patients (Meagher et al., 2015).

Future research should prioritize an in-depth exploration of the impact of these social barriers on the accessibility of rehabilitation services and to various medical settings. Understanding the complex dynamics underlying these disparities is essential for the development of targeted interventions aimed at reducing healthcare inequalities and safe discharge planning among diverse racial and ethnic populations.

Health Insurance Type

Health insurance type was a significant co-variate in all three studies. In Study One, our results illustrated that using patients with Medicaid insurance as the reference group, patients with private insurance were 1.35 times and 1.47 times more likely to receive OT (OR= 1.35, 95% CI [1.08, 1.70]); and PT (OR= 1.47, 95% CI [1.16, 1.87]), respectively. Likewise, patients with Medicare insurance were 1.49 times and 1.47 times more likely to receive OT (OR= 1.49, 95% CI [1.12, 1.98]); and PT (OR= 1.47, 95% CI [1.09, 1.98]), respectively. Using patients with private insurance as the reference group, patients with Medicaid insurance were 0.90 times and 0.91 times less likely to experience shorter wait times to receive both OT (HR= 0.90, 95% CI [0.83-0.98]) and PT (HR= 0.91, 95% CI [0.83-0.98]) services. This result aligns with prior research, which consistently highlights the challenges faced by patients with Medicaid insurance in obtaining early access to healthcare services (Albrecht et al., 2017; Alcalá et al., 2018; Gao et al., 2018).

In Study Two, using patients with Medicaid insurance as the reference group, we observed that patients with private insurance had lower odds of being discharged to the community following PT (OR= 0.76, 95% CI [0.59, 0.97]). This finding aligns with a recent study indicating that patients with public insurance were more likely to discharge to the community relative to those with private insurance (Sorensen et al., 2020).

In Study Three, our findings indicated that patients with managed care were less likely to be readmitted compared to those with public insurance (OR= 0.52, 95% CI [0.30, 0.88]). This result is consistent with previous studies that have shown lower readmission rates among patients with managed care compared to patients with public insurance (Agarwal et al., 2021; Jacobs & Basu, 2020; Jung et al., 2020).

The impact of financial barriers, such as insurance type, on the accessibility of rehabilitation services, discharge disposition, and risk of readmission is a pressing issue that warrants further investigation. Future studies should delve into these financial determinants and their influence on access to rehabilitation services, discharge disposition, and unplanned hospital readmission across different healthcare settings and systems. Such research can provide valuable insights into the measures needed to address these disparities and ensure equitable access to healthcare services, and safe discharge planning, and unplanned hospital readmission for all individuals, regardless of their insurance status.

Injury Severity and Comorbid Conditions

Injury severity and comorbid conditions were significant co-variates in all three studies. In Study One, our findings revealed significant disparities in access to rehabilitation services based on TBI severity and comorbidity burdens. Our results indicated that using patients with severe TBI as the reference category, patients with moderate TBI were 3.39 times and 3.68 times more likely to receive OT (OR= 3.39, 95% CI [2.01, 5.70]); and PT (OR= 3.68, 95% CI [2.17, 6.24]), respectively. Patients with greater comorbidity burden (i.e., functional comorbidity index [FX-TBI-CI] scores) were 0.95 times less likely to receive both OT and PT services (ORs = 0.95, 95% CIs [0.89, 0.98]) compared to patients with lower comorbidity burden. When considering the timing of rehabilitation services, using patients with mild TBI as the reference category, patients with severe TBI were 0.80 times less likely to experience shorter wait times to receive OT (HR= 0.80, 95% CI [0.65-0.98]). These findings are consistent with prior research indicating that patients with severe TBI and greater comorbidity burdens tend to face longer delays in the onset of rehabilitation services relative to those with mild or moderate TBIs and lesser comorbidity burdens (Béavogui et al., 2015; Mehmood et al., 2021a).

In Study Two, our findings elucidated significant differences in community discharge based on TBI severity and comorbidity burdens. Our results indicated that Using severe or moderate TBIs as reference categories, patients with mild TBI were 1.26 to 2.28 times more likely to be discharged to the community (OT model: Mild vs. moderate TBI OR= 1.26, 95% CI [1.00, 1.58]); Mild vs. Severe TBI OR= 2.28, 95% CI [1.23, 4.23]), PT model: Mild vs. moderate TBI OR= 1.30, 95% CI [1.03, 1.63]); Mild vs. Severe TBI OR= 1.97, 95% CI [1.11, 3.50]). Patients with greater comorbidity burden (i.e., functional comorbidity index [FX-TBI-CI] scores) were 0.91 to 0.93 times less likely to be discharged to the community (OR= 0.93, 95% CI [0.90, 0.96]) in OT model and (OR=0.91, 95% CI [0.88, 0.94]) in PT model. These findings are consistent with prior research indicating that patients with greater TBI injury severity and comorbidity burden were less likely to discharge to the community relative to those with lesser TBI injury severity and comorbidity burden (Lu et al., 2022; Sastry et al., 2022).

In Study Three, our results showed that patients with mild TBI severity were less likely to be readmitted than their moderate TBI counterparts (OR = 0.53, 95% CI [0.29, 0.96]). This finding reinforces the consensus in previous research, indicating that more severe TBI cases are more likely to be readmitted (Hoffman et al., 2020; Li et al., 2018; Saverino et al., 2016; Tran et al., 2017).

Future research should examine the influence of TBI severity level and comorbidity burden on the access to and timing of rehabilitation services, discharge disposition, and unplanned hospital readmission. This is essential for guiding efforts aimed at ensuring timely and equitable access to rehabilitation services, safe discharge planning, and reduce risk of readmission, which, in turn, can enhance patients' independence in self-care and mobility tasks,

contribute to their overall well-being, and allow for more effective strategies for readmission prevention.

Length of Stay

Patients' length of stay was a significant co-variate in both Study One and Study Two. In Study One, our results revealed a significant relationship between length of stay (LOS) in acute care and access to and timing of OT and PT services. Patients with longer length of stay were 1.23 times more likely to receive both OT and PT services (ORs = 1.23, 95% CIs [1.18, 1.27]). This finding is consistent with previous literature indicating that longer LOS was associated with receiving more rehabilitation services (Woznowski-Vu et al., 2015). On the other hand, our results showed that patients with longer lengths of stay were 0.99 times and 0.94 times less likely to experience shorter wait times to receive OT (HR=0.99, 95% CI [0.99-1.00]), and PT services (HR=0.94, 95% CI [0.93-0.94]), respectively. The link between LOS and access to and timing of rehabilitation services may be attributed to patients' functional or mobility status.

In Study Two, our findings revealed a significant relationship between LOS in acute care and the likelihood of community discharge. Patients with longer LOS were less likely to be discharged to the community following rehabilitation services (ORs = 0.86, 95% CIs [0.84, 0.88]). This finding aligns with previous literature indicating that patients with longer length of stay were less likely to discharge to the community relative to those with shorter stays (Oyesanya, 2020; Oyesanya, Harris, Yang, et al., 2021). The influence of LOS on discharge disposition could be related to patients' functional and physical status, impacting community discharge.

Further studies are needed to examine the impact of patients' LOS and accompanied functional and mobility levels and their associations with access to and timing of rehabilitation

services, and safe discharge planning. These investigations can offer valuable insights into tailoring rehabilitation services to meet the specific needs of patients at different stages of recovery, ensuring that access and timing are optimized for each individual's unique circumstances.

DIRECTIONS FOR FUTURE RESEARCH

Together, these three studies provide preliminary evidence for the need for further research examining the impact of several community and person level factors on individuals with TBI acute care rehabilitation utilization and outcomes. One way to increase understanding of these studies is to replicate findings in additional health systems to determine if results translate to geographically diverse patients with TBI. Our dataset had no information about prior health status; thus, future research should explore the influence of patients' prior health status on onset of rehabilitation services and outcomes. Our dataset lacked information about the referral date to rehabilitation services; therefore, future research should include referral dates to better address the timing of rehabilitation services in acute care. All SDoH variables in Study One were based on community-level data. While our findings revealed no significant associations, it is crucial for future research to investigate the impact of person-level SDoH on the access to and timing of rehabilitation services among individuals with TBI. This shift towards examining individual-level SDoH variables can offer a more nuanced perspective on the potential determinants of rehabilitation service accessibility and timing.

Additionally, we did not include cognitive assessment data in our analyses because of standardized cognitive assessments are often not administered to all patients in acute care settings or are not recorded in standard electronic medical record flow sheets. Future studies should examine the influence of patients' cognitive status, if available, on patients' discharge

disposition and readmission status. Our dataset had no information on home health OT/PT. Future research should explore the influence patients' home health OT/PT on ADL/mobility improvement and specific discharge location, and readmission status. Our study did not examine specific discharge destinations, such as Inpatient Rehabilitation Facility (IRF) versus skilled nursing facility; instead, discharge disposition was categorized broadly into community versus institutional. Future research should explore the association between OT/PT utilization and specific discharge destinations to provide a more detailed understanding of the determinants of discharge location among patients hospitalized with TBI in acute care settings.

CONTRIBUTIONS TO OCCUPATION AND REHABILITATION SCIENCE (ORS)

Contributions to the Field of Occupation Science (OS)

My research has contributed to OS in several ways. It has provided evidence of the complexity of human occupations and the impact of context on occupational engagement (Clark et al., 1991; Dickie, 2006). This research builds on the knowledge base around factors influencing the delivery of rehabilitation services in TBI patients while also generating knowledge about factors that shape access to acute care services and outcomes following hospitalization. Through looking into predictors of early access, this research showed evidence of how occupational engagement promotes health and well-being (Larson, 2003; Yerxa, 1990). Many studies documented that timely access to therapy has positive effects on patients' outcomes (Andelic et al., 2012; Bernhardt et al., 2017; Middleton, Downer, et al., 2018; C. Y. Wang et al., 2021). Lastly, my research has contributed to a better understanding of how context can lead to injustice by examining social, physical, and cultural factors influencing the transaction between the person and environment (Dickie, 2006; Townsend & Wilcock, 2004).

Contributions to the Field of Rehabilitation Science (RS)

My research has contributed to RS in various ways. It captures the interaction between the person and environment that influence function, which is a primary focus of RS models (World Health Organization, 2001). This dissertation highlights the critical role of the broader social and cultural contexts in shaping participation experiences in TBI individuals (Pope, 1997). The findings provided valuable knowledge about specific variables such as income, education, and residence location that impact patients' movement along the continuum from disabling to enabling conditions (Law, 2002; Skidmore, 2006; Stucki, 2005). With a better understanding of how rehabilitation services for individuals with TBI look, my research provides practitioners with knowledge to appreciate these influential factors that are beyond their disabilities but prohibit them from benefiting from high quality services. This not only assists therapists who work with this population in using appropriate approaches to target these factors, enable accessibility, and improve outcomes, but also supports TBI individuals in advocating for their needs and rights.

PERSONAL REFLECTION

Navigating through the doctoral journey has been an unparalleled adventure of learning and growth. As I was introduced to the UCHealth's Electronic Health Record, I quickly realized the necessity of delving into the realm of coding and syntax to effectively clean and organize the dataset. This didn't just help me improve my technical skills; it also showed me how crucial it is to keep things well-organized when dealing with numerous large data files. Keeping track of when each file was created became essential in helping me do my tasks with a lot of accuracy.

The significance of trusting the process became evident during prolonged periods of data cleaning, coding, and syntax refinement, where patience was paramount. Some stages required

months of dedication before arriving at a cleaned dataset. This process underscored the iterative nature of observational research with real-world data, emphasizing that the journey to a final product is as crucial as the destination. It involved iterating on the analysis several times, necessitating multiple modifications and alterations, such as the inclusion or exclusion of covariables. Each iteration brought with it new insights, refining the analysis method, and ultimately leading to a more robust and solid set of results.

In parallel, the early exposure to journal publications marked a pivotal aspect of my Ph.D. journey. Crafting manuscripts taught me the art of concise scientific writing, a departure from the extensive documentation often required in class projects. Navigating through the challenge of condensing complex research into a succinct format, I discovered the power of precision in conveying scientific ideas to a broader audience. Traversing the world of scholarly publications, also revealed the resilience needed in the face of rejection. I learned that rejection is not a conclusion but an opportunity for refinement. Each setback encouraged me to work harder, seek alternatives, and persist until my work found its place in the scholarly domain. Submitting manuscripts also sharpened my skills in responding to reviewers. This iterative dialogue with reviewers not only strengthened the quality of my work but also instilled in me a deep appreciation for constructive criticism and the continuous improvement inherent in the academic process.

Participation in local and international conferences from my second year added a new dimension to my academic journey. Engaging with the wider scientific community not only enriched my perspective but also provided a platform to present my developing research. Interacting with audiences from different disciplines and varied expertise levels expanded my

ability to consider their questions, comments, and feedback, contributing to the continual refinement and enhancement of my research.

As I conclude this chapter of my academic journey, I carry forward a profound appreciation for the multifaceted aspects of research from managing dataset to mastering scientific communication. This experience has shaped not just my academic abilities but also my resilience, patience, and commitment to the pursuit of knowledge. Looking ahead, I am eager to contribute further to my field, armed with the valuable lessons learned during this remarkable journey.

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APPENDIX A

Severity level definition based on ICD-10 codes for TBI.(Defense and Veterans Brain Injury Center, 2015)

Severity level	ICD-10 codes	
	Codes Prefixes	Codes suffixes
Mild	S02.	110A, 110AA, 11BA, 112, 112A, 11EA, 11FA, 113, 113A, 8XXA, 80XA, 81XA, 82xA
	S06.	0X0A, 0X1A, 0X9A
Moderate	S06.	0X2A-0X4A, 1X, 1X0A-1X4A, 1X9A, 2X, 2X0A-2X4A, 2X9A, 30, 300A-304A, 309A, 31, 310A-314A, 319A. 32, 320A-324A, 329A, 33, 330A-334A, 339A, 34, 340A-344A, 349A, 35, 350A-354A, 359A, 36, 360A-364A, 369A, 37, 370A-374A, 379A, 38, 380A-384A, 389A, 4X, 4X0A-4X4A, 4X9A, 5X, 5X0A-5X4A, 5X9A, 6X, 6X0A-6X4A, 6X9A, 9X, 9X0A-9X4A, 9X9A,9X9S, 89, 890A-894A, 899A.
	S02.	0XXA, 10, 10XA, 101A, 102A,109A,111, 111A, 11CA, 11DA, 118, 118A, 118GA, 11HA, 119, 119A, 19, 19XA, 91, 91XA
	S07.	1, 1XXA
Severe	S04.	02, 02XA, 03, 031A, 032A, 039A, 04, 041A, 042A, 049A
	S06.	0X5A-0X8A, 1X5A-1X8A, 2X5A-2X8A, 305A-308A, 315A-318A, 325A-328A, 335A-338A, 345A-348A, 355A-358A, 365A- 368A, 375A-378A, 385A-388A, 4X5A-4X8A, 5X5A-5X8A, 6X5A-6X8A, 895A- 898A, 9X5A-9X8A.

APPENDIX B

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why

Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15*	Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives

Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

APPENDIX C

Counting minutes for service units

Number of service units	Number of minutes
1	(≥ 8 minutes through 22 minutes)
2	(≥ 23 minutes through 37 minutes)
3	(≥ 38 minutes through 52 minutes)
4	(≥ 53 minutes through 67 minutes)
5	(≥ 68 minutes through 82 minutes)
6	(≥ 83 minutes through 97 minutes)
7	(≥ 98 minutes through 112 minutes)
8	(≥ 113 minutes through 127 minutes)

Reference: Colorado Department of Health Care Policy and Financing (HCPF). (2023, July 7) Billing manuals. Retrieved November 13, 2023, from https://hcpf.colorado.gov/ptot-manual#units