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ORIGINAL PAPER

Changes in Jail Admissions Before and After Traumatic Brain Injury

Joseph A. Schwartz[1,2] · **Emily M. Wright**[3,4] · **Ryan Spohn**[3,4] · **Michael F. Campagna**[3,4] · **Benjamin Steiner**[3] · **Ebonie Epinger**[3]

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Abstract

Objectives Traumatic brain injury (TBI) is differentially concentrated within incarcerated populations. Despite the consistency of this observation, the timing of within-individual changes in criminal justice contact in relation to TBI remains under-investigated. For example, previous studies have primarily considered TBI as a causal influence of later criminal justice contact. However, TBI may also serve as a consequence of criminal justice contact or a criminogenic lifestyle. The current study simultaneously observes both possibilities by examining criminal justice contact before, around the time of, and after the first reported TBI.

Methods Drawing from a combination of self-report and lifetime official record data from a jail cohort admitted between February 2017 and September 2017 and who sustained their first reported TBI at age 21 or older ($N=531$), the current study examines jail admissions in the 24 months before and 24 months after the first reported TBI and across eight biannual intervals ($N=4{,}248$ person-periods).

Results Any and misdemeanor admissions slightly increased pre-TBI and continued to increase around the time of and following TBI, never returning to pre-TBI levels. Felony admissions remained stable around the time of injury and increased post-TBI. Further analyses that incorporated a comparison group revealed that these patterns are unique to the TBI group and not a result of a larger systematic process.

Conclusions These findings indicate that the probability of jail admission is greatest post-TBI, but also increases leading up to sustaining a TBI.

Keywords Traumatic brain injury · Collateral consequences · Criminal justice contact · Jail

✉ Joseph A. Schwartz
jaschwartz@fsu.edu

1 College of Criminology and Criminal Justice, Florida State University, 304A College of Criminology and Criminal Justice Building, 145 Convocation Way, Tallahassee, FL 32306-1273, USA

2 Center for Social and Humanities Research, King Abdulaziz University, Jeddah, Saudi Arabia

3 School of Criminology and Criminal Justice, University of Nebraska at Omaha, Omaha, NE 68182-0149, USA

4 Nebraska Center for Justice Research, University of Nebraska at Omaha, Omaha, NE 68182-0149, USA

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Intoduction

The Center for Disease Control and Prevention defines traumatic brain injury (TBI) as a disruption to normal brain function caused by a bump, blow, or jolt to the head (Centers for Disease Control and Prevention 2017). Each year, TBI results in nearly 2.5 million emergency department visits, 282,000 hospital admissions, and approximately 56,000 deaths, with the most common TBI sources including unintentional falls, being unintentionally struck by or against an object, and motor vehicle accidents (Taylor et al. 2017). As these numbers indicate, TBI is a relatively common condition, with approximately 8–12% of the adult population in the United States sustaining a TBI at some point in their lives (Frost et al. 2013). Even more troubling than the rate of TBI in the general population is the differential concentration of TBI among specific subpopulations. For example, multiple meta-analyses and population studies have indicated that 51–60% of incarcerated individuals have sustained a TBI, a rate that is five to eight times greater than the general population (Farrer & Hedges 2011; Shiroma et al. 2010).

Despite the consistency of these findings, questions remain regarding the within-individual changes in criminal justice contact[1] in relation to the timing of TBI. The bulk of the previous research examining the association between TBI and criminal justice contact has framed *TBI as a causal influence*, resulting in subsequent increases in criminal justice contact (Connolly & McCormick 2019; Schwartz 2019; Schwartz et al. 2017). However, findings from a complementary literature suggest that *TBI may be a consequence* of a criminogenic lifestyle (Fazel et al. 2016; Fazel & Baillargeon 2011; Massoglia & Pridemore 2015; Schreck et al. 2006). While previous research has not directly examined this possibility, related findings provide preliminary support. Based on these findings, the current study aims to address the following research question:

> Does TBI contribute to increases in the probability of subsequent jail admissions, or does jail admission increase the probability of subsequently experiencing a TBI?

In order to examine this research question, we employ a unique dataset comprised of lifetime jail admissions records for a cohort of justice involved individuals. The current study extends prior research by examining jail admissions *24 months before and 24 months after* the first reported TBI. This approach offers at least three advantages over previous research. First, considering admissions both before and after the first reported TBI provides greater insight into more granular changes in the longitudinal trajectory of jail admissions in relation to the timing of TBI. Second, our focus on a jail population is notable, as previous research examining justice involved populations has been almost exclusively limited to prison populations, raising concerns about the extent to which such findings extend to other, more heterogenous justice involved populations. Third, the current study also incorporates a comparison group (i.e., members of the examined jail cohort who did not sustain

[1] We acknowledge that the term "criminal justice contact" may evoke a wide range of processes that include informal interactions with law enforcement, arrest, conviction, incarceration, and reentry to the community. The goal of the current study is not to examine all of these intricate and intertwined processes, as such an inquiry would move far outside of the research questions examined. Rather, the use of "criminal justice contact" within the context of the current study refers to the fact that the examined outcomes are measured using jail admissions, which are an, albeit imperfect, proxy for arrest but do not necessarily reflect conviction or incarceration. For this reason, we use this term in a narrower application than what may have been used in previous studies.

a TBI) to examine the robustness of the observed trajectories of jail admissions before, around the time of, and after TBI.

Traumatic Brain Injury And Criminal Justice Contact

The association between TBI and criminal justice contact has been reported extensively and appears to be robust (Farrer & Hedges 2011; Shiroma et al. 2010). Despite this support, previous research has yet to examine changes in criminal justice contact in relation to the timing of TBI to better understand the extent to which these changes occur before, around the time of, and following a TBI. This oversight limits our understanding of the ways TBI and criminal justice contact may influence one another, consequently shaping criminal trajectories over important stages of the life course. With this in mind, there are at least two ways that TBI and criminal justice contact may be related to one another. Prior to discussing both possibilities, it is important to note that both hypotheses are largely *modular* and are not intended to be mutually exclusive.

Traumatic Brain Injury as a Causal Influence

First, it is possible that TBI, and the biological changes that accompany injuries to the brain, may result in increases in behavior problems, and subsequent increases in formalized social responses in the form of criminal justice contact. A significant number of studies have reported findings in support of this hypothesis. Such studies typically report increases in behavior problems or criminal justice contact *after* sustaining a TBI, or a greater concentration of behavior problems among those who have sustained a TBI compared to those who have not (Fazel et al. 2011; Jackson et al. 2017; Ray & Richardson 2017; Sariaslan, et al. 2016a, b; Sariaslan et al. 2016a, b; Schwartz et al. 2017, 2019). A smaller number of studies have reported increases in behavior problems and criminal justice contact stemming from within-individual changes in TBI over time (Schwartz 2019; Schwartz et al. 2018, 2020). While these studies provide preliminary support for TBI as a causal influence, they do not effectively examine changes in criminal justice contact as a function of the timing of TBI, as they fail to consider prior contacts in a detailed manner. However, these findings provide evidence in support of what we refer to as the causal influence hypothesis, which can be stated as:

Causal Influence Hypothesis: The probability of jail admission will increase and remain elevated following a TBI .

Traumatic Brain Injury as a Consequence

Second, it is also possible that a combination of internal and external influences, including the deleterious experiences that accompany criminal justice contact, may subsequently increase the probability of sustaining a TBI. This possibility frames TBI as a consequence rather than a causal influence. While previous studies have not directly examined this hypothesis, there are at least two convening lines of research that provide preliminary support. First, propensity theories point to internal influences and traits as primary motivating factors that ultimately promote criminal behavior and subsequent criminal justice contact (Dean et al. 1996; Wright et al. 2001). One notable example would be Gottfredson and Hirschi's (1990) self-control theory, which posits that criminal behaviors, as well as analogous and deviant behaviors, are the result of low levels of self-control resulting in selection into risky environments that simultaneously increase the probability of sustaining a TBI and criminal justice contact. This possibility is further underscored by lifestyle theories, in which underlying traits may differentially expose individuals to environments where victimization and other adverse outcomes may be more likely to occur (Pratt & Turanovic 2016; Schreck et al. 2006).[2]

The second way that TBI may be a consequence of criminal justice contact is via differential exposure of justice involved individuals to social contexts and circumstances that increase the subsequent likelihood of TBI. Again, this pathway has not been directly examined in previous research, but studies have provided preliminary support, much of which stems from the expansive literature documenting the negative downstream effects of criminal justice contact (Kirk & Wakefield 2018). Justice involvement, and incarceration in particular, is associated with a wide range of deleterious outcomes (Fazel et al. 2016; Visher et al. 2011; Western et al. 2015) and may also result in a significant increase in the probability of sustaining a TBI. For example, justice involved populations are differentially exposed to experiences that are also common sources of TBI, including interpersonal violence (Jennings et al. 2012). Similarly, a nontrivial number of brain injuries occur during periods of incarceration (Fahmy et al. 2020), highlighting the physical consequences of formalized criminal justice contact. Collectively, these findings provide preliminary evidence for what can be referred to as the consequence hypothesis, which can be stated as:

Consequence Hypothesis: The probability of jail admission will increase before sustaining a TBI and remain elevated following injury but will not systematically change in relation to sustaining a TBI.

The Current Study

The current study aims to further explore the differential concentration of TBI within justice involved populations and extends previous research in at least two ways. First, we make use of a novel dataset comprised of a total cohort of individuals admitted to a Midwestern county jail during a six-month period and lifetime official jail admission information to examine within-individual changes in jail admissions *before, around the time of, and after* the first reported TBI. More specifically, we examined the probability of jail admissions in the 24 months before and the 24 months after the first reported TBI. By restructuring the jail admission data around the first reported TBI, the impact of sustaining a TBI on the longitudinal trajectory of jail admission can be probed in far more detail than in previous studies. More specifically, this approach offers a distinct advantage over previous studies, providing a far more precise estimate of not just the direction of change in the probability of jail admission in relation to sustaining a TBI, but also *when* such changes occur. Further, and as detailed above, this approach allows for a more direct, and simultaneous, examination of both the causal influence and consequence hypotheses. The current study also examines the robustness of these findings with additional analyses that included a comparison group that did not sustain a prior TBI but who still possess similar,

[2] Importantly, it remains possible that TBI may still serve as a proximate cause of criminal justice contact in this scenario, but the ultimate cause would be attributed to internalized traits and influences. This possibility further underscores the bidirectional nature of these two hypotheses and demonstrates the importance of emphasizing their modularity in a causal framework.

group-level, characteristics to those who did sustain a TBI. This additional analysis further clarifies the results, as any systematic similarities between the TBI and comparison groups would reflect a more general process that universally impacts both groups. However, if both groups display different patterns of jail admission across the study period, such results would provide additional support for the importance of TBI in differentiating between the observed patterns.

Second, the current study examines a jail cohort. This extension of previous research is important, as few studies have systematically examined TBI within jail populations (Glover et al. 2018; Slaughter et al. 2003), instead focusing on prisons (Farrer & Hedges 2011) or specific at-risk samples (Schwartz 2019; Schwartz et al. 2017, 2020). Without question, jail and prison populations have some overlap, as virtually all individuals are held in jails prior being transferred to prison. Despite this observation, important differences between jail and prison populations have been previously documented (Bronson et al. 2017; Bronson & Berzofsky 2017), indicating that findings from the existing literature may not directly map onto other incarcerated populations. The cohort examined in the current study includes all intakes across an eight-month period, ranging from first-time offenders to chronic, repeat offenders and from those who were arrested for minor offenses (e.g., first offense, non-injury driving under the influence) to those who were arrested for serious, violent offenses and are awaiting trial. In this sense, the examined sample provides a broader snapshot for studying the impact of TBI, as compared to prison samples, which (by definition) are limited to individuals convicted of felony offenses. Moreover, the examined sample affords an opportunity to also examine "public nuisance" offenders, who often experience mental health issues and frequently cycle in and out of jail facilities (Bronson et al. 2017; Bronson & Berzofsky 2017). Thus, our reliance on a jail cohort allows us to examine the role of TBI for individuals committing frequent, minor offenses, in addition to individuals committing more serious offenses and eventually end up in prison. The examination of a jail population also affords the opportunity to include a sizable number of females in the examined cohort, offering another distinct advantage, as few studies have examined the association between TBI and criminal justice contact among females (O'Rourke et al. 2018; Wall et al. 2018). Collectively, the use of a jail cohort allows us to re-examine the association between TBI and the jail admissions in a group may differ in important ways from the samples observed in previous studies.

Methods

Data Source and Study Population

Between February 21 and September 12, 2017, all individuals admitted to a large Midwestern county jail were screened in-person by trained reentry specialists with a customized inventory. These assessment activities were aimed at identifying the risks and needs of the population of intakes, to monitor their flow into and out of the institution, and to determine rates of recidivism. Screening occurred at the time of intake or within the first few days of jail admission. This procedure resulted in a total cohort of 4,713 incarcerated individuals. Cohort members were booked for a wide variety of offenses, with the most common being arrested on bench warrant (16.00%), controlled substance possession (7.30%), and domestic assault (4.10%). As is typical with a jail-based sample, the total time served for the cohort was relatively short with a large variance. Cohort members remained incarcerated for nearly 126 days ($M = 125.93$,

$SD = 194.52$), but with a large range spanning from 0 days served (i.e., released on the same day as admission) to 871 days. The median number of days served was 18. The subset of the cohort examined in the current study ($n = 531$) was limited to members who met two inclusion criteria. First, only cohort members that reported their first lifetime TBI at age 21 or later were retained to ensure official jail admission data were available for a full 24 months before the first reported injury (i.e., when individuals were age 19 or older).[3] Admissions that occur prior to age 19, the age of criminal responsibility for the state in which the examined jail was located, are handled by the juvenile justice system and were not available. Second, cohort members incarcerated for the entire 24-month follow up period were excluded to ensure follow up data were available.[4] Biannual jail admissions were structured around the midpoint of the year of the first reported TBI, allowing for the examination of jail admissions 24 months before and after, resulting in a total of 4,248 (531 individuals across eight biannual study intervals) person-periods.[5]

In order to examine the robustness of the findings from analyses examining this subgroup of the cohort, we also drew a comparison group from the overall cohort. The comparison group was limited to all cohort members who reported that they had not sustained a previous TBI and met all of the remaining selection criteria employed to identify the treatment (i.e., TBI) group. Since members of the comparison group did not report a TBI, there is no corresponding age to examine jail admissions in the 24 months before and after. To address this issue, we used a random forest imputation approach to impute an estimated "pseudo-age" at first TBI. This imputation procedure incorporates principles of machine learning and has been found to perform better than alternative imputation procedures (Stekhoven & Bühlmann 2012). The resulting estimates reflect the age in which each member of the comparison group would be expected to have first sustained a TBI if they would have done so. In order to retain balance between the comparison and treatment groups, only those cohort members with a pseudo-age that was greater than or equal to 21 were retained in the final comparison sample. These selection criteria resulted in a final subsample of $n = 1{,}092$ individuals ($n = 8{,}736$ person periods).

Outcome Measures

Lifetime jail admission information was obtained from the county in which the examined jail was located. Admissions were limited to new dockets, indicating a new offense, and

[3] Of the 4,713 individuals included in the examined cohort, 544 (or approximately 12%) reported a TBI before the age of 21.

[4] As described in the main text, data were structured around the midpoint of the year in which the first TBI was reported, so the "24 month follow up period" does not necessarily refer to the 24 months that follow release from the offense that occurred during the recruitment period (February 21, 2017 and September 12, 2017). Rather, it refers to the 24 months that follow the midpoint of the year in which the first TBI was reported. Structuring the data in this way and the availability of lifetime admissions data allowed us to retain a much larger number of cohort members, increasing variability and statistical power and is also necessary to examine structured changes in admissions in relation to the timing of TBI.

[5] The decision to employ biannual intervals was driven primarily by limited month-to-month variation in admissions (particularly for felony admissions). More specifically, only one study month displayed any admission prevalence that exceeded 5% (6 months post the mid-point of the year in which the first TBI was reported). This pattern was even more pronounced for felony admissions, in which only one study month displayed a prevalence that exceeded 3% (13 months post the midpoint of the year of the first reported TBI) and several months with a prevalence of less than 1%. For these reasons, we decided to pool the monthly intervals into biannual intervals.

omitting admissions pertaining to previous offenses, such as those stemming from a probation or parole violation. Importantly, admissions measured this way are a proxy for arrests and legal conviction. For each admission, the date and the classification of the most serious criminal offense—felony or misdemeanor—were recorded. Each incident was then mapped to the appropriate biannual period in relation to the midpoint of the year of the first reported TBI. The resulting period specific admissions measures were coded 0 = *no admissions* and 1 = *one or more admissions* for each six-month interval. Felony and misdemeanor admissions were coded similarly. This coding strategy resulted in a total of three outcome measures: any admissions; felony admissions; and misdemeanor admissions.

Traumatic Brain Injury

TBI was assessed using the Ohio State University Traumatic Brain Injury Identification Method (OSU TBI-ID), a common and validated self-report instrument (Corrigan & Bogner 2007) previously employed in correctional settings (Glover et al. 2018; Ray & Richardson 2017; Wall et al. 2018). This instrument is designed to capture information on lifetime TBI prevalence, timing, and severity, as well as the circumstances surrounding injuries and has been discussed in detail elsewhere (Corrigan & Bogner 2007). Briefly, the instrument is divided into three "steps" which are comprised of a series of questions that are delivered by trained interviewers. The first step consists of five questions focused on the lifetime prevalence of a physical injury to one's head or neck that: (1) resulted in a hospitalization; (2) was the result of a car or moving vehicle accident; (3) was the result of being hit by something or occurred while playing sports; 4) being hit, shaken, or shot by someone; or (5) was the result of being close to a blast or explosion. For each reported injury, individuals were asked if: (1) they lost consciousness following the injury; and (2) their age when the injury occurred. The individual's age at the time of the *first reported TBI*, in conjunction with their date of birth, was used to find the calendar year in which the TBI occurred. Since information pertaining to the precise month of the first reported TBI was unavailable, the midpoint of the year in which the TBI occurred was used as the center point (i.e., Time 0) of the constructed person-period dataset with biannual intervals ranging from 24 months pre-TBI (i.e., Time -24) to 24 months post-TBI (i.e., Time 24).

Covariates

The employed analytic procedures leverage the panel-based design of the person-period dataset to isolate within-individual changes in jail admissions over the study period (Horney et al. 1995; Rabe-Hesketh & Skrondal 2012; Singer & Willett 2003). However, between-individual differences must still be addressed using more traditional controls. With this in mind, we included a series of covariates in all multivariable models to minimize confounding. First, age at first reported TBI was assessed with the OSU TBI-ID and measured continuously in years. Second, a dummy indicator variable reflecting whether the first reported TBI resulted in a loss of consciousness (0 = *no* and 1 = *yes*) was included. Third, since jail admissions are far less common during periods of incarceration, the proportion of each biannual interval in which individuals were incarcerated was included in the multivariable models as a time-varying offset term. Fourth, self-reported sex, was measured dichotomously (0 = *female* and 1 = *male*). Fifth, race was also self-reported (White, Black, Hispanic, or other) and entered as a series of dummy indicator variables with White serving as a reference category.

Plan Of Analysis

Generalized Additive Models

The adjusted probability of jail admissions across the study period was examined using specialized class of generalized additive models (GAMs) (Wood, 2003, 2017). This approach, an extension of generalized linear models (GLMs), is recommended in situations where the functional form of an association is unknown and allows for the introduction of nonparametric covariates. This seems reasonable for the current study, as the primary research objectives are centered around examining changes in jail admissions before, around the time of, and after TBI. Since GAMs make no underlying assumptions regarding the functional form of an association, they appear well-suited for this application.

GAMs replace traditional parametric predictors (i.e., fixed effects) with summed smooth functions adjusted for the other covariates included in the model. To better illustrate, a traditional GLM with a logistic link function can be reformulated as a GAM

$$\log\left(\frac{p_i}{1-p_i}\right) = \eta_i + X_i^*\theta + f\left(x_i\right) \tag{1}$$

where p_i is the probability of a jail admission, η_i is the intercept, and X is a vector of parametric covariates with accompanying parameters θ. The addition of the $f\left(x_i\right)$ function is what differentiates a GAM from a GLM, as GLM applies a linear function and then simplifies $f\left(x_i\right)$ as x_i. Alternatively, a GAM replaces this linear function with a nonparametric function that is commonly referred to as a smoother or smoothing spline (for a more detailed overview, see chapters 5 and 6 in Wood 2017). For the current study, we make use of thin plate regression splines, which directly address limitations of other approaches (e.g., restricted cubic splines) and have been described as “something of an ideal smoother” (Wood 2017, p. 216). Nonparametric smooth functions do not produce traditional regression coefficients in the way that linear functions (i.e., GLMs) do, rather the coefficients are “absorbed into the function itself” (Berk et al. 2010, p. 198). For this reason, results from nonparametric covariates are typically presented graphically as predicted values, but parametric covariates can be presented in a more traditional manner as fixed effects.

The traditional GAM framework can accommodate panel data by extending Eq. 1 into a generalized additive mixed model (GAMM)

$$\log\left(\frac{p_{it}}{1-p_{it}}\right) = \eta_i + X_{it}^*\theta + f\left(x_{it}\right) \tag{2}$$

such that p_{it} is the probability of a jail admission for person i at time t, and the parametric parameters, θ, are now essentially akin to fixed effects. Importantly, η_i is a random intercept, which results in efficient standard errors. Equation 2 is well-suited to examine the probability of jail admission both before and after the first reported TBI

$$\log\left(\frac{p_{it}}{1-p_{it}}\right) = \eta_i + X_{it}^*\theta + f\left(\mathrm{TIME}_{it}\right) \tag{3}$$

where TIME represents the number of study intervals before or after the first reported TBI and centered at the midpoint of the year in which the first TBI was reported and entered into the equation as a nonparametric smoothing function, f. The results provide an estimate of the predicted probability of jail admission, adjusted for all included covariates, for each study interval. A total of seven sets of models were estimated.

First, two sets of baseline models were estimated. In the first set, time was modeled as a parametric covariate (akin to a fixed effect), to demonstrate general changes in jail admissions across the study period. This step of the analysis is aimed to provide a direct point of comparison for prior research examining the association between TBI and criminal justice contact, as this analytic approach has been frequently employed in previous studies (see for example Schwartz 2019). Second, using Eq. 3, time was entered as a nonparametric smoothing spline to more closely examine fluctuations in the probability of jail admission from one study interval to the next. In line with general recommendations for the presentation of GAMM findings (Berk et al. 2010; Wood 2003, 2017), the results for the *TIME* coefficient (as specified in Eq. 3) are presented as predicted probabilities along with accompanying 95% confidence intervals for each study interval. Importantly, the resulting predicted probabilities were adjusted for all included covariates. Unlike the nonparametric parameters, parametric parameters (i.e., θ in Eq. 3) can be presented as traditional coefficients and interpreted the same way as fixed effects. Since the parametric covariates are largely included the estimated models as statistical controls, the accompanying results are presented in the accompanying supplemental material, while the results from the parametric covariates are presented graphically below. The script used to estimate all study models as well as the coefficients and accompanying inferential statistics for all parametric covariates are also presented in the accompanying supplemental material. All multivariable models were estimated with all covariates in *R* version 3.6.1 (R Core Team 2019) using packages mgcv version 1.8.31 (Wood 2017) and nlme version 3.1.145 (Pinheiro et al. 2020).

Discontinuity around The Time of Injury

While GAMs are extremely flexible and assume no functional form regarding the examined association, it is possible that more extreme changes may occur around the time of TBI, a possibility that is further exacerbated by the fact that the precise month in which the first reported TBI occurred was unknown. In order to better address this possibility, the next set of models allowed for discontinuity around the time of injury and was modeled as

$$\log\left(\frac{p_{it}}{1-p_{it}}\right) = \eta_i + X_{it}^{*}\theta + d_{it}\beta + f_1\left(\text{TIME}_{it}\right) + f_2\left(\text{TIME}_{it} \times d_{it}\right) \tag{4}$$

where d_{it} is a nominal variable coded 1 for the 18 months comprising the pre-TBI time period, 2 for the 12 months immediately surrounding the TBI, and 3 for the 18 months comprising the post-TBI time period. Discontinuity was modeled as the interaction term, $f_2\left(\text{TIME}_{it} \times d_{it}\right)$, which allows for the estimation of separate smooth functions for each level of d_{it}.

Introduction of a Comparison Group

The next step of the analysis involved the incorporation of a comparison group that did not sustain a TBI during the entire study period. In an effort to retain as many cases as possible in the comparison group, a traditional matching procedure was substituted with entropy balancing, a specialized weighting procedure that is considered "doubly robust," as it allows for the calculation of a more traditional propensity score but also further refines these scores via covariate balancing (Zhao & Percival 2017). Like any other weighting procedure, entropy balancing begins with an average treatment on the treated (ATT) procedure in which the comparison group is weighted to match the treatment group across the primary variables of interest. Since all members of the treatment group (i.e., the TBI group) had sustained a TBI, they received a weight of 1. The resulting weights for the comparison group are then adjusted for relevant covariates. Simulations have revealed that entropy balancing has been found to outperform alternative weighting methods, such as propensity score modeling (Zhao & Percival 2017). The covariates included in the balancing procedures were selected based on theoretical relevance as well as mean comparison and X^2 tests. More information, including a list of included covariates and the results of the balancing procedures, are provided in the accompanying supplemental materials (Table S1). The probability of jail admission across the TBI and comparison groups was estimated as

$$\log\left(\frac{p_{it}}{1-p_{it}}\right) = \eta_i + X_{it}^{*}\theta + TBI_i\beta + f_1\left(\mathrm{TIME}_{it}\right) + f_2\left(\mathrm{TIME}_{it} \times TBI_i\right) \tag{5}$$

where TBI_i is a binary indicator that differentiates between those in the TBI (1) and comparison (0) groups. To maintain balance between the two groups, the entropy weight was included in the model as a parametric covariate. In addition, since the comparison group did not sustain a TBI, the loss of consciousness measure was constant and therefore excluded from the equation.

Supplemental Analyses

In order to examine the robustness of the findings from the primary analysis, three additional sets of GAMMs were estimated. More specifically, these models were aimed at addressing the extent that any observed association between TBI timing and jail admission is moderated by additional sources of influence. First, to more directly compare the probability of jail admission before and after TBI across sex, Eq. 3 was respecified as

$$\log\left(\frac{p_{it}}{1-p_{it}}\right) = \eta_i + X_{it}^{*}\theta + \mathrm{SEX}_i\beta + f_1\left(\mathrm{TIME}_{it}\right) + f_2\left(\mathrm{TIME}_{it} \times \mathrm{SEX}_i\right) \tag{6}$$

which includes the interaction term, $f\left(\mathrm{TIME}_{it} \times \mathrm{SEX}_{it}\right)$, allowing for the estimated smooth function to vary across sex and resulting in separate trajectories for males and females. Second, it is also possible to allow the nonparametric time term to vary across whether the first reported TBI resulted in a loss of consciousness

$$\log\left(\frac{p_{it}}{1-p_{it}}\right) = \eta_i + X_{it}^{*}\theta + LOC_i\beta + f_1\left(\mathrm{TIME}_{it}\right) + f_2\left(\mathrm{TIME}_{it} \times LOC_i\right) \tag{7}$$

where *LOC* is a dummy indicator coded 1 if the first reported TBI resulted in a loss of consciousness and 0 otherwise. Third, it is possible that systematic changes in jail admission across the study period may be due to maturation processes (Rocque, 2015) or aging more broadly. To examine this possibility, the final estimated equation can be expressed as

$$\log\left(\frac{p_{it}}{1-p_{it}}\right) = \eta_i + X_{it}^{*}\theta + \mathrm{AGE}_i\beta + f_1\left(\mathrm{TIME}_{it}\right) + f_2\left(\mathrm{TIME}_{it} \times \mathrm{AGE}_i\right) \tag{8}$$

where AGE_i represents the age at which the first TBI was reported. Age was entered as a continuous covariate, allowing for a closer examination of possible changes in the probability of jail admission across study intervals and the entire range of ages observed.

Results

Preliminary Analyses

Table 1 presents the means, standard deviations, percentages, and case counts of all study measures. The final subset of the cohort consisted of more males (66.85%) than females (33.15%) and a majority identified as White (57.63%). The sample was approximately 32 years old at the time of their first reported TBI ($M = 32.27$, $SD = 9.57$), approximately 70% (70.06%) experienced a loss of consciousness following their first reported TBI, and experienced approximately two additional TBIs following their first ($M = 2.29$, $SD = 0.51$). Over 60% (61.39%) of the sample experienced at least one jail admission during the 48-month study period, with 33.90% experiencing one or more felony admissions, 48.59% experiencing at least one misdemeanor admission. The sample spent the vast majority of each biannual study interval in the community, with an average of only 3% ($M = 0.03$, $SD = 0.10$) of each interval incarcerated.

Panel A of Fig. 1 presents jail admission prevalence across all eight study periods. For all jail admissions (one to six months post injury, 21.66%; *95% CI* = 18.36%, 25.37%)

Table 1 Injury and participant characteristics

Variables	Percentage or mean	*n*
Admission prevalence, %		
Any	61.39	326
Felony	33.90	180
Misdemeanor	48.59	258
Characteristic of Injury		
Age at time of injury, mean (SD), y	32.27 (9.57)	
Loss of consciousness, %	70.06	372
Participant characteristics, mean (SD)		
Percentage of study period incarcerated	0.03 (0.10)	–
Sex, %		
Male	66.85	355
Female	33.15	176
Race, %		
White	57.63	306
Black	29.76	158
Hispanic	4.52	24
Other	8.10	43

Proportion of six-month study interval incarcerated was calculated by dividing the number of days incarcerated by the total number of days in each six-month study interval

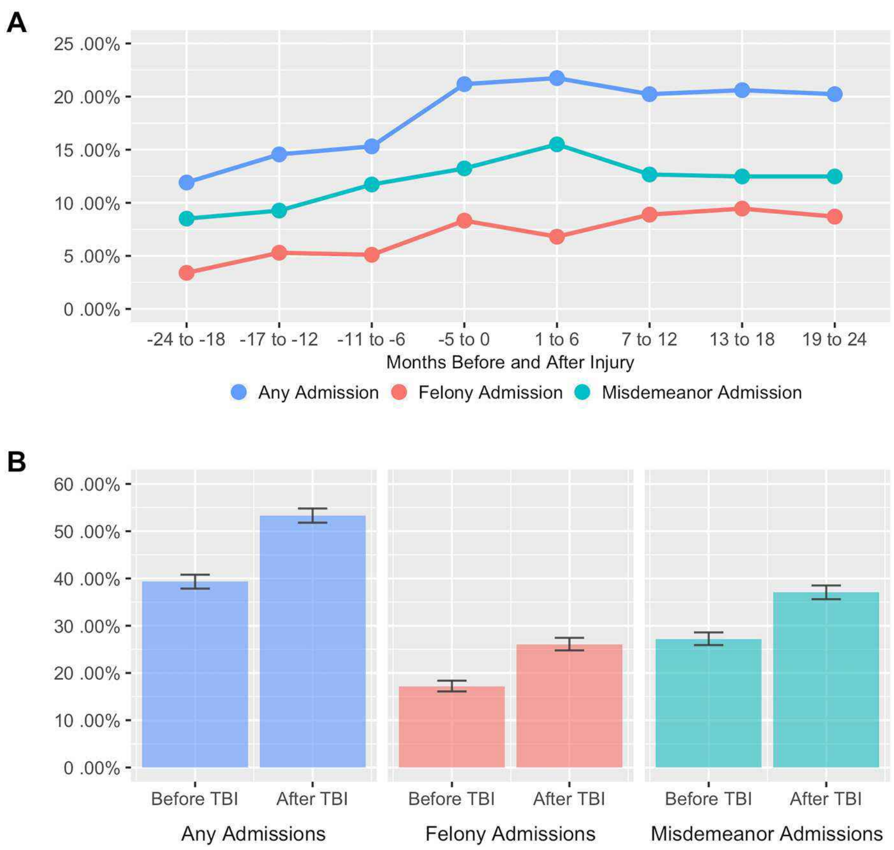

Fig. 1 Changes in Jail Admissions over the Study Period and Comparisons of Admissions Before and After Traumatic Brain Injury. **a**, The moving proportion of cases that experienced a jail admission for each 6-month study interval. **b**, The proportion of cases that experienced jail admissions before and after the midpoint of the year in which the first TBI was reported. Error bars represent accompanying 95% confidence intervals. $N=531$ ($N_{\text{Person-Periods}}=4{,}248$)

and misdemeanor admissions (one to six months post injury, 15.44%; *95% CI* = 12.61%, 18.77%), prevalence peaks within the 12 months in which the first TBI occurs, with a slight increase prior to the year of the first TBI, decreases slightly following TBI, and then levels off in the 18 months post-TBI. For felony admissions, prevalence increased slightly leading up to the year surrounding the first TBI, decreased during the injury period (one to six months post TBI, 6.78%; *95% CI* = 4.93%, 9.26%), and continued to increase post-TBI, peaking 13 to 18 months later (9.42%; *95% CI* = 7.21%, 12.21%). The proportion of all ($X^2[7]=34.93$, $P<0.001$), felony ($X^2[7]=27.36$, $P<0.001$), and misdemeanor admissions ($X^2[7]=18.10$, $P=0.012$) significantly varied across all eight study periods.

Panel B of Fig. 1 presents the prevalence of jail admissions before and after the midpoint of the year of the first reported TBI. 39.36% of the sample experienced a jail admission before the midpoint compared to 53.48% post-TBI, a 35.87% increase ($X^2[1]=96.71$, $P<0.001$). 17.33% experienced a felony admission pre-TBI compared to 25.99% post-TBI, a 49.97% increase ($X^2[1]=46.53$, $P<0.001$). 27.12% individuals experienced a misdemeanor admission, compared to 37.29% post-TBI, a 37.50% increase ($X^2[1] = 37.42$, $P < 0.001$). Thus, all examined admissions significantly increased post-TBI.

Adjusted Probability of Jail Admissions Before and After TBI

The next step of the analysis involved the estimation of a mixed GLM to examine general changes in jail admissions across the study period, with the results presented in Table 2. The results revealed that as time progresses toward first TBI, the odds of any jail admission significantly increased, where the probability of any jail admission increased by 9.3% (*OR* = 1.093; *95% CI* = 1.054, 1.133), felony admissions increased by 13.5% (*OR* = 1.135; *95% CI* = 1.075, 1.198), and misdemeanor admissions increased by 5.9% (*OR* = 1.059; *95% CI* = 1.015, 1.105) from one interval to the next. These findings demonstrate the limited information that may be gleaned from traditional GLM models and why previous studies that employ such analytic approaches are unable to provide a detailed understanding of the timing of changes in the probability of jail admissions in relation to sustaining a TBI. More specifically, these results reveal that the probability of admissions increases across the study period but they do not provide sufficient detail to determine *when* the detected increases in the probability of jail admissions occur in relation to the timing of TBI.

Table 2 Multivariable mixed effects regression analysis of jail admission on traumatic brain injury timing

Variable	Admissions		
	Any	Felony	Misdemeanor
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Time	1.093 (1.054; 1.133)	1.135 (1.075; 1.198)	1.059 (1.015; 1.105)
Age at time of injury	1.014 (1.002; 1.026)	1.011 (0.996; 1.026)	1.018 (1.004; 1.032)
Loss of consciousness			
No	1 [Reference]	1 [Reference]	1 [Reference]
Yes	1.415 (1.088; 1.840)	1.556 (1.103; 2.192)	1.232 (0.915; 1.660)
Proportion of days incarcerated	1 [Offset]	1 [Offset]	1 [Offset]
Sex			
Male	1 [Reference]	1 [Reference]	1 [Reference]
Female	0.891 (0.693; 1.145)	0.734 (0.529; 1.018)	0.974 (0.732; 1.295)
Race			
White	1 [Reference]	1 [Reference]	1 [Reference]
Black	1.773 (1.371; 2.294)	1.419 (1.027; 1.960)	1.788 (1.336; 2.392)
Hispanic	1.467 (0.841; 2.559)	1.405 (0.705; 2.801)	1.344 (0.706; 2.559)
Other	1.277 (0.814; 1.966)	1.181 (0.676; 2.064)	1.444 (0.877; 2.377)
Intercept	0.052 (0.021; 0.090)	0.017 (0.009; 0.034)	0.033 (0.018; 0.060)

Time variable centered at the midpoint of the year in which first traumatic brain injury was reported. The proportion of days in each 6-month study interval was included in the estimated model as an offset term. $N = 531$ ($N_{\text{Person-Periods}} = 4{,}248$)

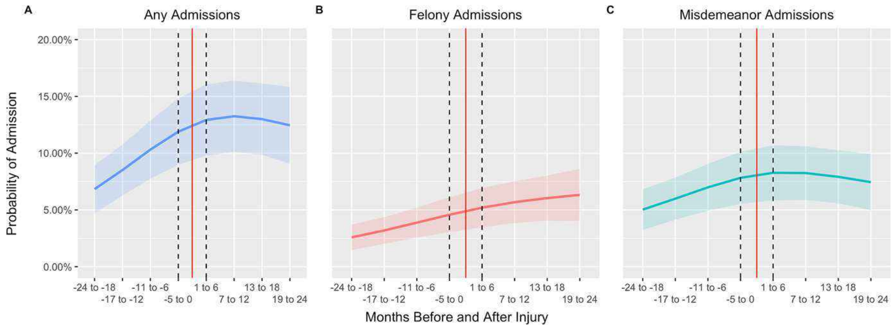

Fig. 2 Generalized Additive Mixed Models Examining the Probability of Jail Admission Before and After Traumatic Brain Injury. Solid lines represent the predicted probability of admission for each 6-month study interval. Shaded confidence bands represent the accompanying 95% confidence intervals for each predicted value. All probabilities were adjusted for all study covariates. The solid red line represents the midpoint of the year in which the first TBI was reported (i.e., Time 0) and the accompanying dashed lines represent the surrounding 12 months (six before and six after). Accompanying coefficients are presented in the online supplemental material. **a**, predicted probabilities of any admission. **b**, predicted probabilities of felony admissions. **c**, predicted probabilities of misdemeanor admissions. $N=531$ ($N_{\text{Person-Periods}}=4{,}248$)

The next step of the analysis involved the estimation of a series of GAMMs using Eq. 3 to examine changes in jail admissions across the study period. The predicted probabilities of jail admission estimated from the smooth function of the time measure as described above, along with the accompanying 95% confidence intervals, across the study period (adjusted for all model covariates) is presented in Fig. 2, with accompanying coefficients for all parametric covariates presented in the supplemental material (Table S2). In each panel, the midpoint of the year in which the first TBI was reported is denoted using a solid red line (i.e., Time 0) and the six months before (i.e., Time -5 through Time 0) and the six months after (i.e., Times 1 through Time 6) the injury are denoted using dashed black lines to better represent the pre- and post-TBI periods. Panel A of the figure presents the predicted probability of any admission across the study period. The probability of any admission increased steadily leading up to the TBI, continued to increase in the year surrounding the injury, and leveled off post-TBI. However, *the probability of admission never returned to pre-TBI levels*. Panel B presents the probability of a felony admission, which was more linear, with increases leading up to the injury period and continuing to increase post injury. Finally, Panel C presents the probability of a misdemeanor admission, the pattern of which resembles the any admission trajectory but flatter.

Discontinuity Around The Time of Injury

The next step of the analysis re-estimated the previous GAMMs but used Eq. 4 to allow for discontinuity in the predicted probability of admission to better account for more extreme changes before, during, and after the injury period. The results from the discontinuity models are presented in Fig. 3, with the accompanying coefficients presented in the supplemental material (Table S3). Panel A presents the probability of any admission during the study

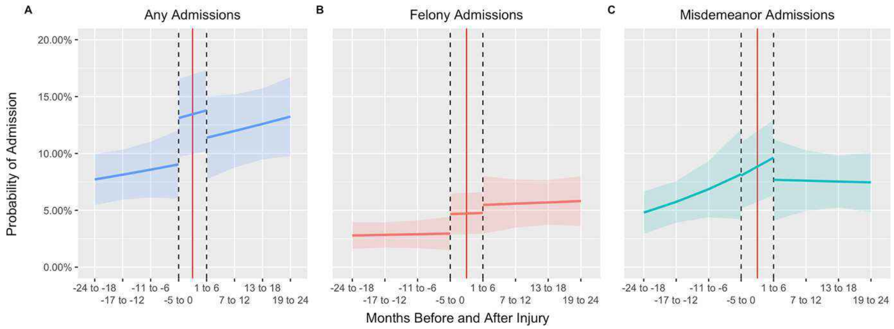

Fig. 3 Generalized Additive Mixed Models Examining the Probability of Jail Admission with Discontinuity Before and After Traumatic Brain Injury. Solid lines represent the predicted probability of admission for each 6-month study interval. Shaded confidence bands represent the accompanying 95% confidence intervals for each predicted value. All probabilities were adjusted for all study covariates. The solid red line represents the midpoint of the year in which the first TBI was reported (i.e., Time 0) and the accompanying dashed lines represent the surrounding 12 months (six before and six after). Accompanying coefficients are presented in the online supplemental material. **a**, predicted probabilities of any admission. **b**, predicted probabilities of felony admissions. **c**, predicted probabilities of misdemeanor admissions. $N = 531$ ($N_{\text{Person-Periods}} = 4{,}248$)

period, and once again, the probability increased slightly leading up to TBI, increased more dramatically in the 12 months surrounding the injury, and then leveled off, but continued to increase post injury. The probability of a felony admission is presented in Panel B and displayed a similar pattern in which the probability of a felony admission increased slightly leading up to the study period and then increased further but remained stable during the 12 months surrounding the injury before continuing to slightly increase post injury. Finally, the probability of misdemeanor admissions is presented in Panel C. The overall trajectory for misdemeanor admissions largely resembled the pattern for any admissions but demonstrated a more consistent probability of admission post-injury. Once again, for all three types of jail admissions, the probability of admission post-TBI never returned to pre-TBI levels.

Patterns across Comparison Groups

The results from GAMMs that fit Eq. 5 are presented in Fig. 4, with accompanying coefficients presented in the supplemental material (Table S4). The probability of any, felony, and misdemeanor jail admissions across the study period for the TBI group mirrors the results from previous models. Alternatively, the pattern for the comparison group (i.e., those who have not sustained a TBI) across all three examined outcomes appears to be virtually flat and does not covary with the midpoint of the study period in any systematic way.

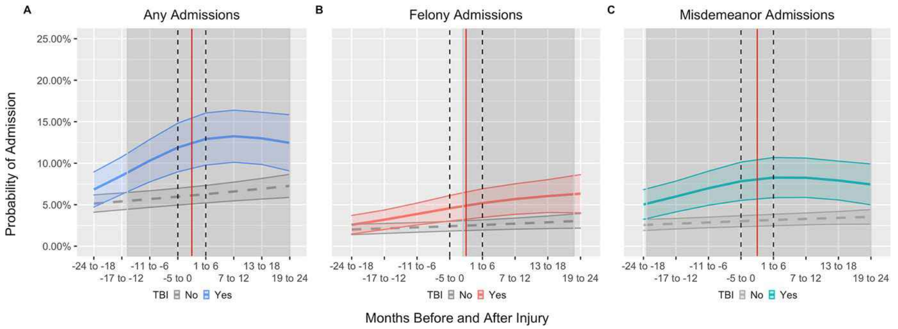

Fig. 4 Generalized Additive Mixed Models Comparing the Probability of Jail Admission for the TBI and Comparison Groups. Solid lines represent the predicted probability of admission for each 6-month study interval. Shaded confidence bands represent the accompanying 95% confidence intervals for each predicted value. All probabilities were adjusted for all study covariates. The solid red line represents the midpoint of the year in which the first TBI was reported (i.e., Time 0) and the accompanying dashed lines represent the surrounding 12 months (six before and six after). Accompanying coefficients are presented in the online supplemental material. Shaded regions represent predicted probabilities in which the accompanying 95% confidence intervals do not overlap for the two examined groups. **a**, predicted probabilities of any admission by loss of consciousness. **b**, predicted probabilities of felony admissions by loss of consciousness. **c**, predicted probabilities of misdemeanor admissions by loss of consciousness. $N = 1{,}623$ ($N_{\text{Person-Periods}} = 12{,}984$)

This is an important finding, as a more general process, such as maturation or aging more broadly, would be expected to produce a pattern that resembles that observed in the TBI group, as such processes would be expected to impact both groups in equal measure. The relatively flat trajectories observed in the comparison group provides evidence that there is something unique about the TBI group and the time period examined, providing greater confidence in the results observed in the previous models.

Supplemental Moderation Analyses

In order to further examine the robustness of the findings presented in the main analysis, and examine the extent to which such findings are potentially moderated by other sources of influence, three additional supplemental analyses were estimated. The results of the supplemental analyses are presented in the accompanying supplemental material. First, Eq. 6 was used to examine sex differences in the probability of jail admissions across the study period. The results are presented in Figure S1, with the accompanying coefficients presented in Table S5. Panel A presents the probability of any jail admission for males (solid blue line) and females (dashed gray line). As can be seen in the Figure, the predicted probabilities for each biannual interval do not significantly vary across sex (as evidenced by the overlapping 95% confidence intervals). A similar pattern was observed for both felony (Panel B) and misdemeanor admissions (Panel C), with nonsignificant differences in trajectories for males and females. Second, Eq. 7 was used to examine the extent to which the findings from the primary analysis are moderated the severity of injury. The results are presented in Figure S2 with the accompanying coefficients presented in Table S6. Panel A displays the probability of any jail admission across the study period for those who did (i.e., dashed gray line) and those who did not (i.e., solid blue line) experience a loss of consciousness with the first reported TBI. The two trajectories begin to significantly deviate during the 12 months surrounding the study period and in the months that immediately follow, wherein those individuals who experienced a loss of consciousness display a significantly greater probability of admission relative to those who did not experience a loss of consciousness (highlighted in the shaded region of the figure). Importantly, however, the probability of admission eventually converges in the post injury period. A similar pattern can be observed for felony admissions and is presented in Panel B. Finally, the probability of a misdemeanor admission for both groups are presented in Panel C. As can be seen, the two trajectories do not significantly diverge, with both groups displaying similar patterns of misdemeanor admissions across the study period.

Third, to examine the extent to which the examined findings are moderated by more general age-based pattern, the final set of supplemental models were fit a model using Eq. 8. Since the age that participants first sustained a TBI ranges between 21 and 67 years, the total grid surface examined consisted of 47 age groups and eight time intervals. The results are presented as three-dimensional surface plots in the supplemental material (Figures S3-S5), with the accompanying parametric coefficients presented in Table S7. The surface plots present the study intervals across the x-axis, the age at which the first TBI was reported on the y-axis, and the probability of jail admission on the z-axis. As can be seen in the figures, the observed trajectory of jail admissions modestly increases as the first TBI age increases, but such increases appear to be nonsignificant[6].

Discussion

Previous research has examined the prevalence of TBI among incarcerated populations (Farrer et al. 2013; Farrer & Hedges 2011; Shiroma et al. 2010) and future criminal justice contact for those who have previously sustained a TBI, pointing to TBI as a causal influence on subsequent criminal justice system contact. However, there is substantial evidence suggesting that TBI may also be a consequence of criminal justice involvement (Fahmy et al. 2020; Jennings et al. 2012) and/or underlying criminal propensities or lifestyle factors (Dean et al. 1996; Pratt & Turanovic 2016; Schreck 1999; Wright et al. 2001). Despite these observations, previous studies have yet to thoroughly examine the timing of changes in jail admissions in relation to sustaining a TBI. The current study addressed this limitation by examining changes in jail admissions before, around the time of, and after sustaining a TBI in a cohort of U.S. adult jail inmates, with the results advancing knowledge in at least three ways.

First, the results of the multivariate GAMMs indicated that the probability of all three forms of jail admission increased leading up to the year of the first reported TBI, providing support for the consequence hypothesis. These findings suggest that incarceration experiences, along with the social, psychological, and physical ramifications that accompany them (Kirk & Wakefield 2018), result in an increased probability of sustaining a TBI. Based on the other negative ramifications that stem from both TBI (Dikmen et al. 2009; McAllister et al. 1999; Polito et al. 2010; Raskin & Rearick 1996; Scott et al. 2015) and justice involvement more broadly (Kirk & Wakefield 2018; Visher et al. 2011; Western

[6] These findings suggest that while the observed association appears to increase with age, a similar pattern was observed across all ages, suggesting that more generic aging processes are not responsible for the examined trajectories of jail admissions.

et al. 2015), this finding has direct implications surrounding reentry and the community-based delivery of programming and services following incarceration. It is also possible, however, that this finding is an indirect result of one of the limitations of our data. More specifically, our sample is limited to individuals who sustained their first TBI at age 21 or later to obtain complete jail admission data for the full 24-month pre-TBI period. This period of the life course is not inclusive of the age of onset and, instead, is more focused on a segment in which the desistance process may be in full effect, or even complete. Therefore, it is at least possible that probability of detecting jail admissions in the pre-TBI period are artificially inflated, leading to the patterns observed. Future research that better incorporates juvenile justice and criminal justice records would be useful in examining a larger swath of the life course and providing greater insight into this possibility.[7]

With that said, previous studies have demonstrated the importance of the selection and delivery of community based programming in reducing recidivism following incarceration (Visher et al. 2017; Zhang et al. 2006). Sustaining a TBI during this same period may undermine these potential benefits. For example, TBI can impair memory (McAllister et al. 1999), increase irritability (Alderman 2003), disrupt sleep, and alter mood (Chaput et al. 2009), all of which may increase the probability of probation or parole violations and future incarceration. Limited research has provided preliminary support for the use of technological aids in addressing some of these consequences (Linden et al. 2016), which offers a promising potential application for criminal justice practitioners and service providers. Despite these findings, future research would benefit from exploring these connections in more detail, the extent to which they assist in minimizing the burden of transitioning back to the general population, and how they can be used to address complications that accompany TBI.

Second, the bivariate analyses and GAMMs also provided support for the causal influence hypothesis. More specifically, the results indicated that the probability of any jail admission and misdemeanor admissions increased in the year surrounding the first reported TBI before continuing to increase but leveling off post-TBI. These results indicate that the greatest probability of criminal justice contact is around the time of and post-TBI and never returned to pre-TBI levels. Importantly, the results from the models that included the comparison group solidified this finding, indicating that these patterns were unique to the TBI group and not the result of a larger more generic process impacting both groups. The probability of admission for the comparison group was relatively consistent over the study period. Importantly, the pattern of criminal persistence observed in the TBI group has been documented in previous research examining the association between TBI and criminal behavior (Schwartz 2019) and suggests that TBI may disrupt normative desistance processes via the introduction of "acquired neuropsychological deficits." The complications of TBI may also be exacerbated by additional risk factors differentially concentrated within jail populations, such as mental health issues and housing insecurity, further perpetuating criminal persistence.

Felony admissions also increased slightly pre-TBI, continued to increase before remaining stable in the 12 months surrounding the first reported TBI, and then slightly increased further post-TBI, with the greatest probability of admission post-TBI. These findings indicate a potentially lagged impact of TBI on more serious offenses, with the greatest likelihood of jail admissions coming months later. These findings align with previously reported

[7] We are grateful to one of the anonymous reviewers for pointing out this possibility.

increases in aggression and severe behavioral problems following TBI (Dyer et al. 2006; Rao et al. 2009), but suggest that such increases may develop more slowly over time. While only speculation, it is possible that this observed delay in more serious behavior problems is ultimately the result of a cascade of other, more immediate symptoms of TBI. For example, previous studies have found that increased levels of depression and poor social functioning within three months of sustaining a TBI were significantly associated with within-individual increases in verbal and physical aggression 12 months following an injury (Roy et al. 2017). Future research more directly aimed at unpacking this possibility would be beneficial and provide a greater understanding of the long-term implications of sustaining a TBI.

Third, the results of the supplemental analyses revealed that the patterns observed in the primary analyses were not moderated by sex or age. However, individuals that reported loss of consciousness following TBI experienced an increased probability of any and felony admissions, but only in the 12 months surrounding the injury and the following months. These findings suggest that more severe injuries may have a more immediate and dramatic impact on behavioral problems, similar to a dose–response relationship, in which the impact of TBI may be more pronounced with more severe injuries, a finding that directly aligns with previous studies (Schwartz 2019; Schwartz et al. 2017). These findings suggest that injury characteristics are important in better understanding the potential negative outcomes that may accompany TBI and should be investigated more thoroughly in future research.

Limitations and Future Directions

This study is not without limitations. First, the current study is observational and unable to determine causality with certainty. With that said, the research design employed—examining within-individual changes in official jail admissions before and after the first reported TBI—is the most robust to date, directly addresses limitations of previous studies, and has been found to perform similarly to randomized controlled trials in previous studies (Berk et al. 2010). Second, jail admission information was only available for the county in which data collection was completed, potentially resulting in an under estimation of the examined outcomes stemming from admissions to jails in other counties. A cursory overview of migration patterns compiled by the U.S. Census over the past 10 years for the examined county appear to closely resemble other, similarly sized counties in the Midwest, suggesting that while some members of our cohort may have left the county over the study period, there is no reason to expect a large, systematic movement of residents out of this county. With that said, a proper and thorough investigation of the mobility of those who come into contact with the criminal justice system within the county examined in the current study is not possible with the data currently available and falls outside of the aims of the current study. However, this issue certainly warrants close attention in future research with a particular emphasis on tracking cohort members' mobility over time. This can be accomplished with follow up self-report instruments or with access to official record data from surrounding counties. Further, while there are some distinct advantages of examining jail admissions, shifting focus to arrests may allow for more complete official data, as future studies can draw from criminal history data maintained by the FBI. Regardless of the design employed, future research aimed at thoroughly tracking mobility as well as TBIs and criminal justice contact would be extremely beneficial in providing greater insight into the research question examined in the current study as well as other, directly connected issues.

Third, in order to access jail admission data for the entire 24-month pre-TBI period, the sample was limited to individuals who reported their first TBI at age 21 or later. This was necessary, as the age of criminal responsibility in the state in which the study was performed is 19, so the minimum age in which 24 complete months of official adult records were available was 21. This can be problematic as the rapid neurodevelopment that occurs during childhood and adolescence may result in increased levels of injury susceptibility (Blakemore 2018), potentially exacerbating the impact of a TBI sustained during this developmental period. Further, limiting our sample in this way dramatically truncates variation in the desistance process, as the age of onset is expected to have occurred several years prior, and we are only able to capture one small segment of the overall desistance pattern displayed for each individual. As discussed above, this limitation may also be one factor contributing to the pre-TBI increase in jail admissions observed. While the associations observed in the current study did not systematically vary by age, future research that combines information from both juvenile and adult official records and examines a larger segment of the life course would offer a powerful extension to the research design employed in the current study.

Fourth and also related to measurement, the OSU TBI-ID (Corrigan & Bogner 2007) relies on retrospective, self-reported information for identification purposes. This strategy is prone to recall bias (McKinlay et al. 2016), potentially resulting in an underestimate of TBI. Despite these limitations, self-report TBI identification methods largely converge with hospital files (Powell et al. 2001) even among incarcerated populations (Schofield et al. 2011) and hospital records are prone to deflated estimates stemming from untreated injuries. In addition to hospital records, measures that tap structural changes to the brain, or emerging biomarkers, would offer greater precision, pointing to the importance of incorporating such measures into future replication efforts and future research more broadly. A more approachable first step for future research may simply be the better integration of both self-report and official documentation pertaining to TBIs, as such information should be more accessible and less invasive than other options. Fifth, precise dates for the first reported TBI were unavailable. The findings of the current study suggest that the association between TBI and jail admission covary in direct relation to TBI timing, emphasizing the importance of future research with more precise measures of when such injuries occur. While it is highly likely that the first TBI does occur within the appropriate study interval (i.e., Time 0), future research would benefit from a more precise measure of TBI timing to better evaluate this association. This objective can be accomplished through the integration of medical records or with more detailed self-report instruments that provide greater precision in injury timing.

Conclusions

Despite these limitations, the results suggest that the probability of jail admissions slightly increases leading up to sustaining a TBI and continues to increase in the months surrounding and following the first reported TBI, never returning to pre-TBI levels. Further, the probability of admissions for more serious offenses appears to follow a similar pattern but does not peak until later in the post-injury period. Collectively, these findings provide some support for a consequence hypothesis in which criminal justice contact slightly increases the probability of sustaining a subsequent TBI. However, the findings provide more consistent support for a causal influence hypothesis, in which the probability of jail admission increases following TBI. With further investigation and development, the findings reported here can assist in providing a better understanding of the ways TBI may increase criminal justice contact, and, even more importantly, inform policy and treatment aimed at minimizing the consequences of such injuries and reducing recidivism.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10940-021-09524-7.

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