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"Interrelationships Between Post-TBI Employment and Substance Abuse: A Cross-lagged Structural Equation Modeling Analysis"

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Previous Presentations
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Abstract

Objective: To describe the interrelationship of post-injury employment and substance abuse (SA) among individuals with traumatic brain injury (TBI).

Design: Structural equation model (SEM) and logistic regression analytic approach using a merged database of the National Trauma Data Bank (NTDB) and TBI Model Systems National Database (TBIMS-NDB), with acute care and rehabilitation hospitalization data and 1, 2, and 5-year follow-up data.

Setting: United States Level I/II trauma centers and inpatient rehabilitation centers with telephone follow-up.

Participants: Individuals in the TBIMS-NDB successfully matched to their NTDB data, aged 18-59 years, with trauma severity, age, sex, employment, and SA data at 1, 2, and/or 5 years post-injury (n=2,890).

Interventions: Not applicable.

Main Outcome Measure: Employment status (employed/unemployed) and SA (present/absent) at year-1, year-2, and year-5 post-injury

Results: SEM analysis showed older age at injury predicted lower likelihood of employment at all time-points post-injury ($\beta_{YR1}=-0.016$; $\beta_{YR2}=-0.006$; $\beta_{YR5}=-0.016$; all $p<0.001$), while higher injury severity score (ISS) predicted lower likelihood of employment ($\beta=-0.008$, $p=0.027$) and SA ($\beta=-0.007$; $p=0.050$) at year-1. Being male predicted higher likelihood of SA at each follow-up ($\beta_{YR1}=0.227$; $\beta_{YR2}=0.184$; $\beta_{YR5}=0.161$; all $p<0.10$). Despite associations of pre-injury unemployment with higher pre-injury SA, post-injury employment at year-1 predicted SA at year-2 ($\beta=0.118$, $p=0.028$). Employment and SA during the previous follow-up period predicted subsequent employment and SA respectively.

Conclusions: Employment and SA have unique longitudinal interrelationships and are additionally influenced by age, sex, and ISS. The present work suggests the need for more research on causal, confounding, and mediating factors and appropriate screening and intervention tools that minimize SA and facilitate successful employment related outcomes.

Keywords

employment; substance abuse; rehabilitation; traumatic brain injury

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Introduction

Traumatic brain injury (TBI) results in a broad spectrum of symptoms and disabilities. In 2013, approximately 2.8 million TBIs occurred in the United States, resulting in over 280,000 hospitalizations,[1] A reported 40% of hospitalizations resulted in long-term physical and cognitive disabilities[2,3] contributing to poor long-term functional outcome and quality of life (QOL).[4-7] Compared to the general population, individuals with TBI more often experience mood disorders,[8,9] unemployment,[10-12] alcohol abuse,[13,14] and substance abuse (SA).[15]

Post-TBI employment is an indicator of both functional outcome and community reintegration.[12,16] Several non-modifiable, injury-related and demographic factors, including younger age, less severe TBI, and male sex,[10,12,17,18] predict higher likelihood of employment post-injury. Understanding and addressing other *modifiable* factors could improve community reintegration, financial independence, and QOL.[12,16,19-21]

SA, including alcohol and drug abuse, is a modifiable, contributing factor to unemployment in the general population.[22-26] Individuals with TBI have elevated pre-injury rates of SA and post-injury alcohol use.[27] History of pre-injury SA contributes to global and neuropsychological impairment post-TBI.[28] Alcohol use post-TBI has also been linked to mood disorders, rehospitalization, and cognitive impairment.[27,29]

Previous research documented mixed results characterizing the relationship between post-TBI SA and employment.[30-32] Most prior research evaluated post-injury SA as an outcome, rather than a factor affecting longitudinal recovery.[13,15,23,32] Though some TBI research has identified high rates of pre-injury SA[28,33] and its association with poor vocational outcome,[29] longitudinal interrelationships between SA and employment post-TBI remain understudied. Though *pre*-injury SA's influence on post-injury employment suggests that SA is an antecedent to employment, we cannot conclude the same *post*-injury. Identifying interrelationships between post-injury SA and employment may provide accurate and meaningful information as to where and when to intervene, and in doing so, strive to improve multi-dimensional, post-TBI recovery.

Individuals with spinal cord injury (SCI) also experience high rates of unemployment[34] Individuals with moderate-to-severe TBI often experience concurrent extra-cranial injury (ECI).[35] Co-occurring TBI and ECI are associated with mortality,[35,36] and suicidal ideation.[37] Higher injury severity score (ISS) has been linked to reduced likelihood of return-to-work in a small cohort study[38] and post-TBI QOL in mild TBI.[39,40] Despite the frequency of ECI post-TBI, no large studies have explored the contribution ECI after moderate-to-severe TBI to longitudinal outcomes.

The primary objective characterized interrelationships between SA and employment among individuals with moderate-to-severe TBI. A secondary objective identified the influence of ISS, a measure of ECI severity, on post-injury SA and employment. This study used a probabilistically-merged dataset from the National Trauma Databank (NTDB) and Traumatic Brain Injury Model Systems National Database (TBIMS-NDB)[41,42] to study the interrelationship between SA and employment and potential effect of ISS as a predictor of outcome post-TBI. This report builds upon previous post-TBI employment and SA research by using a novel dataset, observing both outcomes longitudinally, and uniquely exploring ECI to post-TBI recovery.

Methods

Participants

Data were collected from individuals with moderate-to-severe TBI at 18 TBIMS centers through site-specific Institutional Review Board approved protocols. TBIMS collects data during acute and rehabilitation care and via telephone interviews at 1, 2, and 5 years and every subsequent 5-years post-injury.[43] TBIMS enrolls individuals with moderate-to-severe TBI who are 16 or older, present to a TBIMS acute facility within 72 hours of injury, and receive inpatient rehabilitation at a TBIMS facility.

The presented analyses used a merged dataset of linked TBIMS and NTDB data. Trauma data for two TBIMS centers were deterministically paired, using personal identifiers, from local trauma registries. Trauma data for the remaining TBIMS centers were probabilistically linked to the NTDB, as personal identifiers were unavailable. The merged dataset was previously described and validated.[37,41,42,44] ISS was obtained from the NTDB and all remaining variables from TBIMS.

As employment through 5-years post-injury was a primary outcome, we included participants aged 18-59 at injury to exclude individuals outside of typical working age at any point during the assessment period. Individuals were excluded if they were students at any point. Other exclusion criteria included covariate or outcome data (Figure 1).

Outcomes

Self-reported employment and SA at years-1, -2, and -5 post-injury were primary outcomes. Employment was defined as “employed”, (full and part-time), or “unemployed”, (retirement, work-related leave, unpaid work, volunteering, or household work).

SA was categorized as “present”, indicated by 1) use of illicit drugs, 2) binge drinking during the last month (5 or more drinks at once), OR 3) heavy drinking (14 drinks per week in men, 7 in women), or otherwise as “absent”.[45,46]

Covariates

For all regression and SEM analysis, age, sex, and ISS were evaluated as primary predictors of outcome. ISS is a clinically-assessed, anatomic trauma severity scale that quantifies injury severity by calculating the sum of the squared Abbreviated Injury Scale severity of the 3 most severely injured body regions.[47] ISS scores range from 1 to 75.

Other covariates included pre-injury marital status (Single; Married; Divorced/Widowed), education (<12 years; high school diploma; some college or more), pre-injury employment (employed/unemployed), pre-injury SA (present/absent), post-injury rehospitalization within previous year (yes/no), and TBI severity. TBI severity was categorized as severe for Glasgow Coma Scale (GCS) scores <9, post-traumatic amnesia >1 week, or inability to follow verbal commands >1 day post-TBI.[48]

Additional post-hoc analyses examined the Functional Independence Measure (FIM), employment stability, and drug abuse and alcohol abuse independently. We used Rasch-adjusted FIM cognitive (FIM-Cog) and FIM motor (FIM-Mot) scores, transforming ordinal data into interval scale measurements.[49-51] As reported in a prior TBIMS study,[52] employment stability was categorized into four groups: stable, unstable, delayed, or no paid employment. Lastly in a descriptive, post-hoc analysis, drug and alcohol abuse were assessed separately to observe potential distinct relationships with employment.

Statistical Analysis

Data were summarized as mean [standard deviation (SD)], median (interquartile range [IQR]), or frequency (percentage). We characterized the population and tested significant differences between those with/without SA and between those employed/unemployed, using chi-square tests and Wilcoxon rank-sum or two-sample t-tests. P-values ≤0.05 were considered significant. Our study used a combination of logistic regression models, to explore the cross-sectional interrelationships of employment and SA and cross-lagged structural equation modeling (CLSEM), to explore the longitudinal relationships of employment and SA across follow-up years (Figure 2).

We used a confounder-adjusted CLSEM to assess temporal relationships between two binary endogenous variables, employment and SA, using the diagonally weighted least squares (DWLS) estimation method. CLSEM accounted for the residual covariance between concurrent outcomes, allowing for assessment of bidirectional relationships. CLSEM efficiently and simultaneously analyzes multiple, temporally-dependent relationships. The root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), comparative fit index (CFI) and Tucker-Lewis index (TLI) were observed to test CLSEM fit. We conducted analyses in R (version: 3.2.5), using the *lavaan* package (version: 0.5-23.1097) for CLSEM.[53,54]

Six, cross-sectional logistic regression models evaluated employment and SA at years-1, 2, and 5 respectively. Each model included ISS, age, sex, and both previous and concurrent SA (in the employment models) or employment (in the SA models) as predictors of outcome. These models tested cross-sectional interrelationships between employment and SA at years-1, -2, and -5, shown in Figure 2, supporting our CLSEM results.

We conducted post-hoc analyses to further characterize our results, comparing discharge FIM-Cog and FIM-Mot scores across employment and SA status at years-1, -2, and -5 post-injury via Wilcoxon rank-sum tests. Prevalence of SA, alcohol, and drug abuse at years-1, -2, and -5 post-injury were graphically displayed across employment stability groups.

Results

Participant Characteristics

A total of 2,890 individuals with available employment or SA data at years 1, 2, or 5 were included in this study, 34.39% of which met study criteria for SA at one or more follow-up interviews, 25.20% for alcohol abuse, and 19.68% for drug abuse. Sample characteristics across employment and SA status are presented in Tables 1a and 1b. Individuals employed at year-1 post-TBI tended to be younger, male, more educated, married, with lower ISS, less prevalent pre-injury SA, fewer rehospitalizations, less severe TBI, and more prevalent year-1 SA and pre-injury employment compared to unemployed individuals. Individuals with SA present at year-1 were younger, male, had lower ISS, fewer rehospitalizations, and less severe TBI but tended to be less educated, single, and have higher rates of pre-injury SA compared to individuals without SA.

At years-2 and -5, employed individuals tended to have been previously employed, and those abusing substances tended to have previously abused substances post-injury. Males had a higher proportion of SA at all follow-up. Individuals with pre-injury SA had a higher proportion of post-TBI SA, but lower proportion of employment, across follow-up. Individuals excluded from the CLSEM due to missing data were compared to individuals included in the CLSEM. Excluded individuals were less educated and unemployed (Supplemental Table 2).

Longitudinal relationship assessment

Based on recommended guidelines, model fit indices showed a satisfactory fit for the CLSEM.[55] The RMSEA and SRMR were 0.038 (p-value=0.895) and 0.035 (recommended: ≤0.05), indicating a good fit and small residuals. The CFI and TLI were 0.997 and 0.978 respectively, meeting recommended >0.95 criteria. Values of *standardized* path coefficients (β) greater than 0.50 indicate a large effect, 0.30 a medium effect, and 0.10 a small effect.[56]

The *unstandardized* results of the CLSEM are summarized graphically in Figure 3. Unidirectional arrows display significant regression coefficients. Older age significantly predicted lower likelihood of employment at all follow-up ($\beta_{YR1}=-0.016$; $\beta_{YR2}=-0.006$; $\beta_{YR5}=-0.016$; p's<0.001) and lower likelihood of SA at year-1 ($\beta=-0.022$, $p<0.001$). Higher ISS significantly predicted a lower likelihood of employment ($\beta=-0.008$, $p=0.027$) and SA ($\beta=-0.007$; $p=0.050$) at year-1. Males had a higher likelihood of SA at year-1 ($\beta=0.227$, $p=0.040$). The error covariance between the year 1 employment and SA was 0.199 (p-value<0.001).

Employment at year-1 significantly predicted a greater likelihood of employment at years 2 ($\beta=0.905$, $p<0.001$) and 5 ($\beta=0.624$, $p<0.001$). However, employment at year-2 did not predict later employment. SA at year-1 predicted a greater likelihood of SA at years-2 ($\beta=0.642$, $p<0.001$) and 5 ($\beta=0.374$, $p<0.001$), while year-2 SA also predicted a greater likelihood for SA at year-5 post-injury ($\beta=0.235$, $p=0.004$). Lastly, individuals employed at year-1 had a greater likelihood of positive SA at year-2 ($\beta=0.118$, $p=0.028$). Full CLSEM results, including unstandardized and standardized coefficients, are presented in Supplemental Table 1.

Cross-sectional relationship assessment

Logistic regression results (p-values, odds ratios (OR)) are shown in Table 2. Older age was associated with unemployment at years-1 (OR=0.97, $p<0.001$), -2 (OR=0.97, $p<0.001$), and -5 (OR=0.95, $p<0.001$) and present SA at years-1 (OR=0.97, $p<0.001$) and -2 (OR=0.98, $p=0.008$). Males had an increased likelihood of SA at years-1 (OR=1.44, $p=0.011$), -2 (OR=1.51, $p=0.018$) and -5 (OR=1.53, $p=0.030$). Higher ISS was associated with reduced likelihood of employment (OR=0.99, $p=0.022$) and SA (OR=0.99, $p=0.027$) at year-1.

SA at year-1 was associated with a greater likelihood for concurrent employment (OR=1.45, $p<0.001$). Employment at years-1 (OR=1.44, $p<0.001$), -2 (OR=1.59, $p=0.003$), and -5 (OR=1.58, $p=0.007$) was associated with SA at concurrent follow-up.

Post-hoc analyses

Both individuals who were employed and/or with present SA at years-1 (Figure 4) and -2 (data not shown) had significantly higher median FIM-Cog and FIM-Mot scores at inpatient rehabilitation discharge, indicating greater functional independence (p's<0.001). We used employment stability to observe if changes in post-TBI employment were related to post-injury SA using previously published employment patterns in a TBI-MS national database study.[52] In our sample, 54.53% of individuals were stably employed over 5 years, 8.45% were unstably employed, 10.89% had delayed employment, and 26.13% were unemployed. Prevalence of post-injury SA, including either alcohol abuse or drug abuse specifically, are graphed by employment stability in Figure 5. We observed increasing prevalence of drug abuse across all follow-up time-points in the stable employment group. Alcohol abuse prevalence increased across follow-up years in the unstable, delayed, and stable employment groups, peaking in year-5 for all groups. At 5-years post injury, the stable employment group had the highest prevalence of SA.

Discussion

Our study examines longitudinal associations between employment and SA after moderate-to-severe TBI using a novel CLSEM approach. Our results uniquely identify the unexpected positive association between employment at year-1 and SA at year-2 post-injury and compare SA prevalence across employment stability profiles. The associative relationships shown in our CLSEM (Fig. 3) support this study's *a priori*, hypothesized causal pathway (Fig. 2). This study's results provide preliminary evidence of the longitudinal, cross-lagged interrelationships between SA and employment.

According to the US Department of Health and Human Services, about 24.2% of the general population meet our study's criteria for alcohol abuse (binge drinking or heavy drinking habits) and 10% use illicit drugs.[57] Our cohort's prevalence of alcohol abuse and drug use exceed rates in the general population and SA prevalence exceeds previous lifetime estimates (24%) in individuals with TBI.[58]

Consistent with previous studies, we found that female sex and older age were associated with a reduced likelihood of employment and SA.[59] Older age has consistently been linked to post-TBI unemployment, possibly through exacerbation of existing age-related employment barriers.[10,11] Previous studies have also noted sex differences with regard to employment and SA including differential access to vocational services and perceived poor social support.[60] It is an expected but novel finding that individuals with more severe ECI are less likely to return to work or have SA post-injury. As in SCI, these individuals have worse functional outcomes[34] and likely more barriers to overall activity, including vocational alternatives and access to substances.

Our finding of an association between employment and subsequent SA warrants further exploration and replication. A resumption of higher level of functional activity may encompass both adaptive and negative behaviors, thus the association observed between employment and SA from years-1 to 2. Individuals who are higher functioning, and thus able to resume vocational activity, may also demonstrate greater social integration,[61] and therefore may have greater access to substances. In support of this explanation, we found higher FIM scores in those who were employed *and* those with SA at years-1 and -2.

The positive relationship between year-1 employment and year-2 SA is possibly explained by this study's SA definition. Individuals may return to recreational or rare illicit drug use that does not interfere with participant's employment status, particularly in young individuals where SA may be more socially acceptable. This relationship is also possibly explained by our study's "unemployment" definition. This group included those who retired early and those primarily taking care of the household. Though by definition, these individuals were not employed, they may introduce heterogeneity into the unemployed group. Individuals who are retired or stay at home may have greater life satisfaction and be less likely to have SA than those who are employed or unemployed not by choice. Our data cannot discern whether retirement or taking care of the home was by choice, necessity, or an injury-related circumstance, and so we chose to categorize all unemployment together. Additionally, employed individuals may have increased financial availability of drugs and alcohol and a greater need to manage (i.e. self-medicate) the stresses associated with maintaining a job after injury. Future work must include more detailed examinations of associated variables, such as income and employment type and concurrent mental health factors.

These results have meaningful implications for TBI rehabilitation. First, we demonstrate the importance of assessing relationships among complex extrinsic and intrinsic factors over time post-injury, potentially revealing specific time points for intervention. In this study, while pre-injury SA was associated with post-injury unemployment, those employed at year-1 had a *higher* likelihood of SA at year-2. Return to employment is often considered a successful outcome, but our study suggests that this goal should not be the end of vocational and psychological support, and employment itself may confer some "risk" for individuals post-TBI. Our results indicated unique trends of SA across employment stability, suggesting that post-injury support is continually necessary in employed individuals to prevent or mitigate factors, such as SA, that may cause loss of employment.

Characterizing individuals by employment and SA at year-1 revealed factors that differentiated employment and SA trajectories post-injury. In our cohort younger, male individuals tended to be employed and have positive SA at year-1, while married, more educated individuals had greater prevalence of employment but lower prevalence of SA. Future research should identify similar measures, possibly proxies of resilience (e.g. marital status) and functional reserve (e.g. education) that potentially identify high-functioning, employed individuals at risk for post-TBI SA. Future studies should aim to test the specific relationships of longitudinal employment with drug and alcohol abuse respectively. Additionally, future work from our team will assess possible longitudinal, mental health covariates, like depression, in the employment to SA interrelationship.

Finally, this study provides further evidence that non-neurological injury characteristics affect longitudinal outcomes post-TBI; previous work demonstrated the effects of ECI on suicidal ideation and the effects of early complications – specifically hospital acquired pneumonia – on disability.[37,44] After TBI, neurological injury characteristics consume substantial health provider time and focus, but addressing non-neurological injury characteristics early may support better long-term recovery.

Study Limitations

This study excluded students, a unique population with specific challenges in return to productivity, as well as adults over 60, who may continue to work through retirement age. Additionally, CLSEM requires complete observations, such that individuals included in primary models had complete follow-up data at years-1, -2, and -5 post-injury, possibly biasing results. TBIMS captures individuals who survive their TBI and subsequently receive inpatient rehabilitation, limiting generalizability of these findings to the larger TBI population, which may include underrepresented individuals, more severe injury, or socioeconomically disadvantaged participants likely to be lost to follow-up.[62] Our substance abuse variable combines illicit drug use and alcohol abuse using self-reported use data as is collected by the TBIMS. Lastly, as mentioned earlier, our definition of employment may introduce additional bias by classifying productive but unemployed individuals (e.g. homemakers, volunteers) as "unemployed".

Conclusions

This study captures longitudinal interrelationships of functional outcomes post-TBI, using a unique dataset including acute NTDB and longitudinal TBIMS data and applying CLSEM to multiple TBI outcomes. Our findings elucidated a unique and unexpected *positive* relationship between post-TBI employment and SA and secondarily identified greater ECI severity as predictive of 1-year outcomes post-TBI. Future research should identify concurrent factors influencing this positive relationship between employment and SA and apply CLSEM to understand additional interrelationships among other functional outcomes post-TBI. This work provides key findings to healthcare providers and vocational services programs that may shape programming and support provided to this population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines. No authors have any conflict of interest.

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List of Abbreviations:

CLSEM	Cross-lagged Structural Equation Model
DWLS	Diagonally Weighted Least Squares
ECI	Extra-cranial Injury
FIM-Cog	Functional Independence Measure – Cognitive Subscale
FIM-Mot	Functional Independence Measure – Motor Subscale
GCS	Glasgow Coma Scale
IQR	Interquartile Range
ISS	Injury Severity Score
NTDB	National Trauma Data Bank
OR	Odds Ratio
QOL	Quality of Life
SA	Substance Abuse
SCI	Spinal Cord Injury
SD	Standard Deviation
SEM	Structural Equation Model
TBI	Traumatic Brain Injury
TBIMS-NDB	Traumatic Brain Injury Model Systems National Database

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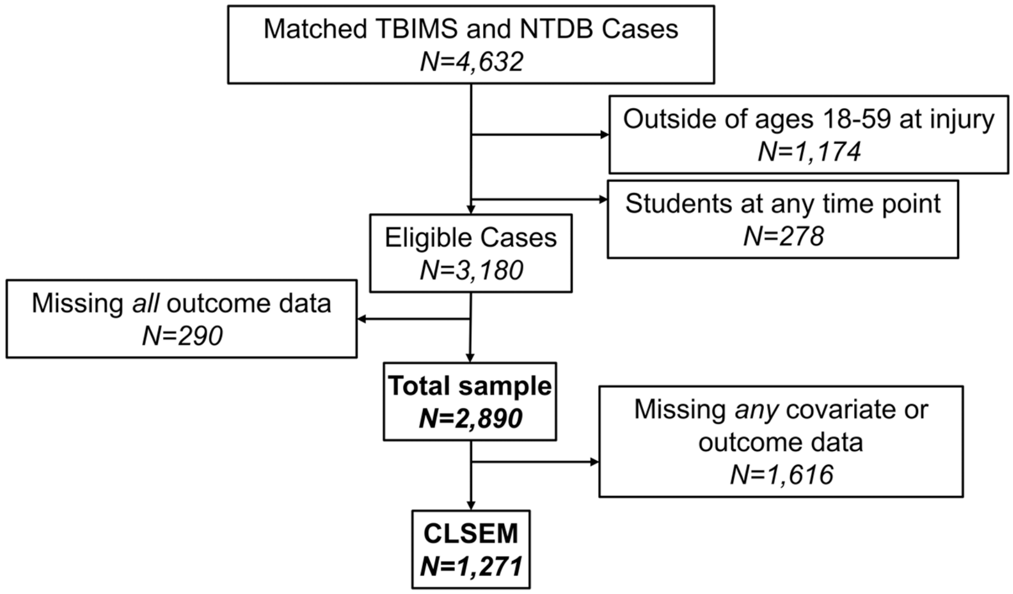
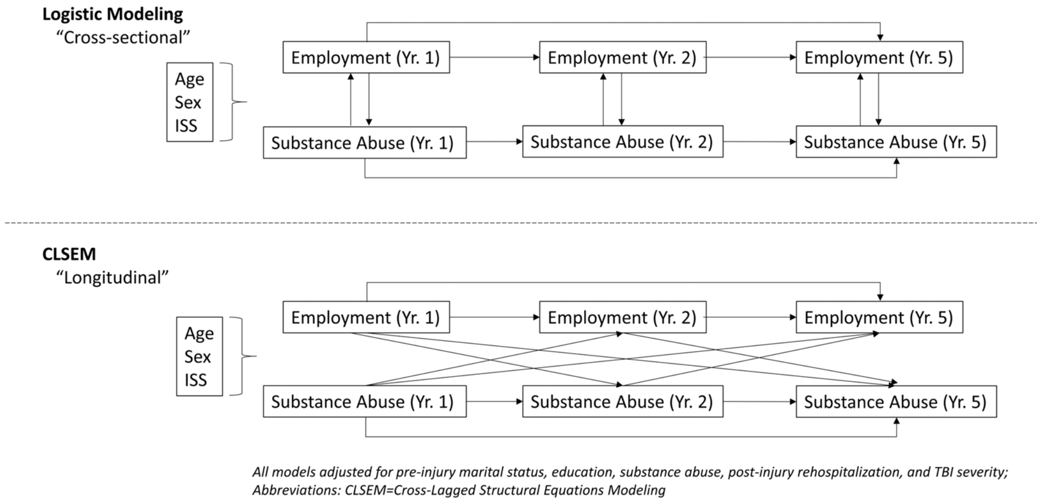


1.

Flow chart diagram of exclusion criteria for total cohort and CLSEM analysis

Flow chart of exclusion criteria and included individuals. Of 4,022 individuals matched across the TBIMS-NDB and NTDB, 3,180 individuals who were between 18- and 59- years old at time of injury and who were not students at any point within 5-years of injury were eligible for inclusion in this study. Of those 2,890 had employment or SA data for at least one follow-up interview, and 1,274 individuals with data for employment SA at all follow-up interviews (as well as included covariates) were included in the CLSEM.

Abb: TBIMS-NDB = Traumatic Brain Injury Model Systems National Database; NTDB = National Trauma Data Bank; CLSEM = Cross-Lagged Structural Equation Model; *SA =* Substance Abuse

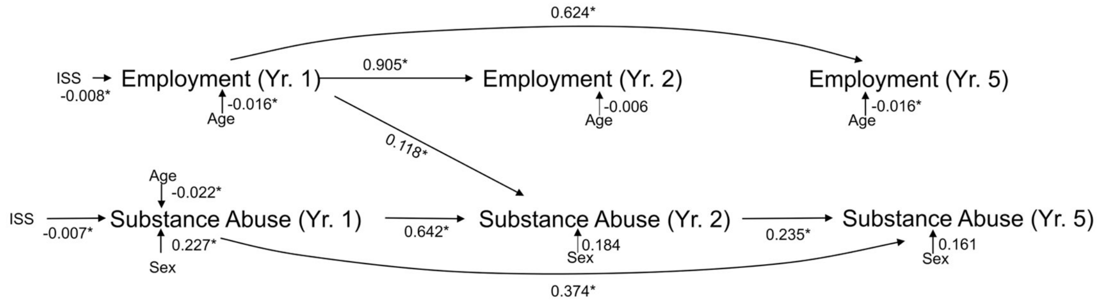


2.

Diagram of relationships explored using logistic regression and CLSEM respectively

Conceptual diagrams are shown to illustrate the specific interrelationships between time-points of employment and SA using logistic modeling compared to CLSEM. Logistic modelling tested relationships between outcomes within one time-point (i.e. cross-sectional) and autoregressive paths within outcomes. CLSEM evaluated the same autoregressive paths, while testing for relationships between employment and SA across follow-up (e.g. year-1 employment and year-2 substance abuse), which was referred to as evaluating "longitudinal" relationships. All models were adjusted for pre-injury marital status, education, substance abuse, post-injury rehospitalization, and TBI severity.

Abb: CLSEM = Cross-Lagged Structural Equation Model; ISS = Injury Severity Score



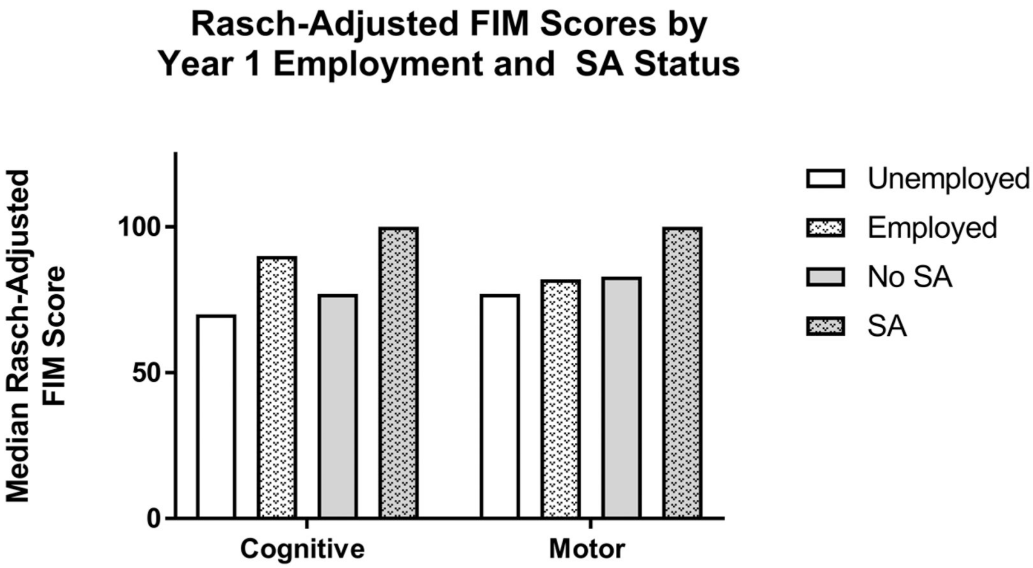
3.

Path diagram of the cross-lagged model

Adjusted for marital status, education, pre-injury employment status, pre-injury substance abuse, rehospitalization, and TBI severity as well as cross-sectional, residual covariances between employment and SA for each year

N=1,271

Significance level: p<0.05 marked by (*), paths for p<0.10 are shown

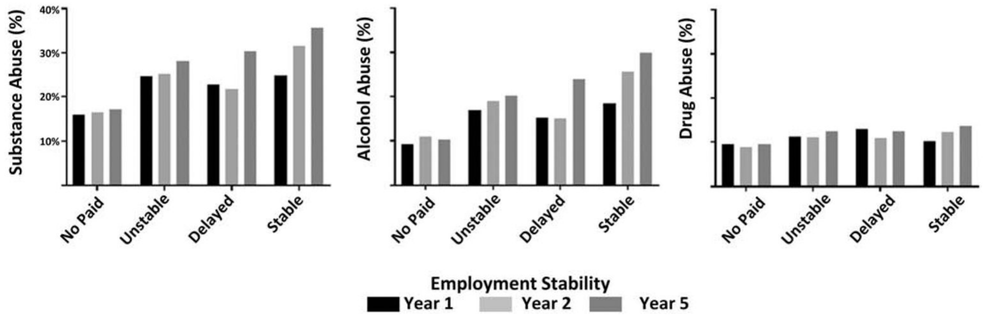


4.

Median Rasch-adjusted FIM-Cog and FIM-Mot scores by year-1 employment and substance abuse (SA) status

Median FIM-Mot and FIM-Cog scores at year-1 follow-up are presented by employment and SA respectively. Differences across employment and SA were tested by Chi-square analyses, with both FIM-Cog and FIM-Mot being significantly lower in individuals who were unemployed at year-1 and with no SA at year-1 (p's<0.001).

Abb. FIM = Functional Independence Measure; FIM-Cog = FIM Cognitive Subscale; FIM-Mot = FIM Motor Subscale; SA = Substance Abuse



5.

Prevalence of post-injury substance, alcohol and drug abuse at year-1, -2, and -5 post-TBI by employment stability

Prevalence of substance abuse (alcohol or drug abuse), alcohol abuse, and drug abuse for years-1, -2, and -5 post-injury are shown by individual's employment stability. Individuals who were stably employed saw increased prevalence of later (year-2 or year-5) substance abuse and drug abuse.

Table 1a:

Population characteristics by Employment

Year 1				
Covariate	**Total (N=2,530)**	**Unemployed (n=1,696)**	**Employed (n=834)**	**P-value**
Age, median [IQR]	35 [24-47]	37 [26-48]	31.5 [23-45]	<0.001 †
Sex (Male), N (%)	1,950 (77.08)	1,289 (76.00)	661 (79.26)	0.067 *
ISS, mean ± SD	25.67 ± 11.55	26.53 ± 11.81	25.30 ± 11.18	0.012 †
SA at year 1 (Yes), N (%)	507 (20.99)	300 (18.62)	207 (25.71)	<0.001 *
Marital status (Married), N (%)	848 (33.53)	536 (31.62)	312 (37.41)	<0.001 *
Marital status (Divorced/Widowed), N (%)	463 (18.31)	356 (21.00)	107 (12.83)	<0.001 *
Education (<=11 years), N (%)	796 (32.21)	641 (38.92)	155 (18.81)	<0.001 *
Education (HS diploma), N (%)	753 (30.47)	518 (31.45)	235 (28.52)	<0.001 *
Pre-injury SA (Yes), N (%)	554 (22.22)	425 (25.51)	129 (15.60)	<0.001 *
Rehospitalization (Yes), N (%)	673 (26.74)	552 (32.72)	121 (14.58)	<0.001 *
TBI severity (Severe), N (%)	2,145 (86.01)	1,463 (87.97)	682 (82.07)	<0.001 *
Pre-injury employment (Yes), N (%)	1,793 (75.91)	1,034 (65.99)	759 (95.47)	<0.001 *
Year 2				
Covariate	**Total (N=2,369)**	**Unemployed (n=1,501)**	**Employed (n=868)**	**P-value**
Age, median [IQR]	35 [24-47]	37 [26-48]	30 [23-44]	<0.001 †
Sex (Male), N (%)	1,812 (76.49)	1,124 (74.88)	688 (79.26)	0.015 *
ISS, mean ± SD	25.67 ± 11.55	26.40 ± 11.77	25.44 ± 11.31	0.052 †
Employment status at year 1 (Employed), N (%)	734 (34.08)	88 (6.53)	646 (80.05)	<0.001 *
SA at year 1 (Yes), N (%)	424 (19.79)	227 (16.95)	197 (19.79)	<0.001 *
SA at year 2 (Yes), N (%)	505 (22.11)	256 (17.79)	249 (29.47)	<0.001 *
Marital status (Married), N (%)	797 (33.66)	480 (32.00)	317 (36.52)	<0.001 *
Marital status (Divorced/Widowed), N (%)	423 (17.86)	325 (21.67)	98 (11.29)	<0.001 *
Education (<=11 years), N (%)	695 (30.99)	550 (39.09)	145 (17.34)	<0.001 *
Education ('HS diploma'), N (%)	696 (31.03)	460 (32.69)	236 (28.23)	<0.001 *
Pre-injury SA (Yes), N (%)	516 (22.16)	375 (25.49)	141 (16.45)	<0.001 *
Rehospitalization (Yes), N (%)	594 (26.62)	452 (32.26)	142 (17.11)	<0.001 *
TBI severity (Severe), N (%)	2,007 (86.03)	1,290 (87.93)	717 (82.79)	0.001 *
Pre-injury employment (Yes), N (%)	1,641 (76.65)	885 (66.04)	756 (94.38)	<0.001 *
Year 5				
Covariate	**Total (N=1,907)**	**Unemployed (n=1,169)**	**Employed (n=738)**	**P-value**

Year 1				
Covariate	**Total (N=2,530)**	**Unemployed (n=1,696)**	**Employed (n=834)**	**P-value**
Age, median [IQR]	35 [24-47]	39 [27-48]	28 [23-42]	<0.001†
Sex (Male), N (%)	1441 (75.56)	867 (74.17)	574 (77.78)	0.074*
ISS, mean ± SD	25.67 ± 11.55	26.44 ± 11.61	25.58 ± 11.31	0.110†
Employment status at year 1 (Employed), N (%)	562 (34.14)	101 (10.25)	461 (69.74)	<0.001*
Employment status at year 2 (Employed), N (%)	625 (37.67)	109 (11.01)	516 (77.13)	<0.001*
SA at year 1 (Yes), N (%)	315 (18.58)	150 (14.71)	165 (24.44)	<0.001*
SA at year 2 (Yes), N (%)	346 (20.98)	163 (16.51)	183 (27.64)	<0.001*
SA at year 5 (Yes), N (%)	452 (24.61)	217 (19.25)	235 (33.1)	<0.001*
Marital status (Married), N (%)	638 (33.47)	377 (32.28)	261 (35.37)	<0.001*
Marital status (Divorced/Widowed), N (%)	357 (18.73)	272 (23.29)	85 (11.52)	<0.001*
Education (<=11 years), N (%)	555 (31.82)	429 (40.63)	126 (18.31)	<0.001*
Education (‘HS diploma’), N (%)	520 (29.82)	325 (30.78)	195 (28.34)	<0.001*
Pre-injury SA (Yes), N (%)	427 (22.70)	292 (25.30)	135 (18.57)	0.001*
Rehospitalization (Yes), N (%)	469 (26.54)	343 (32.09)	126 (18.05)	<0.001*
TBI severity (Severe), N (%)	1,629 (86.56)	1,026 (89.37)	603 (82.15)	<0.001*
Pre-injury employment (Yes), N (%)	1,274 (76.93)	680 (67.53)	594 (91.53)	<0.001*

Column percentages reported

*For categorical variables: p-value was calculated using Chi-square test

†For continuous variable ‘Age at Injury’ p-value was calculated using two-sample Wilcoxon rank-sum (Mann-Whitney) test and for ‘Injury Severity Score’ p-value was calculated using two-sample T-test TBI=Traumatic Brain Injury; ISS=Injury Severity Scale; SA=Substance Abuse

Table 1b:

Population characteristics by SA

Year 1				
Covariate	**Total (N=2,546)**	**No SA (n=2,020)**	**SA (n=526)**	**P-value**
Age at injury, median [IQR]	35 [24-47]	37 [26-48]	27 [22-41]	<0.001 †
Sex (Male), N (%)	1947 (76.47)	1510 (74.75)	437 (83.08)	<0.001 *
ISS, mean ± SD	25.67 ± 11.55	26.32 ± 11.67	24.96 ± 11.48	0.017 †
Employment status at year 1 (Employed), N (%)	805 (33.32)	598 (31.33)	207 (40.83)	<0.001 *
Marital status (Married), N (%)	622 (33.77)	519 (37.34)	103 (22.79)	<0.001 *
Marital status (Divorced/Widowed), N (%)	347 (18.84)	277 (19.93)	70 (15.49)	<0.001 *
Education (<=11 years), N (%)	762 (32.00)	586 (31.10)	176 (35.41)	0.183 *
Education (‘HS diploma’), N (%)	719 (30.20)	578 (30.68)	141 (28.37)	0.183 *
Pre-injury SA (Yes), N (%)	568 (22.60)	348 (17.44)	220 (42.47)	<0.001 *
Rehospitalization (Yes), N (%)	681 (26.75)	558 (27.62)	123 (23.38)	0.050 *
TBI severity (Severe), N (%)	2,157 (85.97)	1,719 (86.69)	438 (83.27)	0.045 *
Pre-injury employment (Yes), N (%)	1724 (75.81)	1380 (76.54)	344 (73.04)	0.128 *
Year 2				
Covariate	**Total (N=2,337)**	**No SA (n=1,818)**	**SA (n=519)**	**P-value**
Age, median [IQR]	35 [24-47]	37 [26-48]	28 [22-41]	<0.001 †
Sex (Male), N (%)	1,782 (76.25)	1,345 (73.98)	437 (84.2)	<0.001 *
ISS, mean ± SD	25.67 ± 11.55	26.07 ± 11.63	26.00 ± 11.74	0.910 †
Employment status at year 1 (Employed), N (%)	719 (34.32)	497 (30.51)	222 (47.64)	<0.001 *
Employment status at year 2 (Employed), N (%)	845 (37.00)	596 (33.50)	249 (49.31)	<0.001 *
SA at year 1 (Yes), N (%)	421 (19.71)	159 (9.49)	262 (56.96)	<0.001 *
Marital status (Married), N (%)	793 (33.95)	687 (37.81)	106 (20.42)	<0.001 *
Marital status (Divorced/Widowed), N (%)	418 (17.89)	332 (18.27)	86 (16.57)	<0.001 *
Education (<=11 years), N (%)	673 (30.83)	532 (31.55)	141 (28.37)	0.375 *
Education (‘HS diploma’), N (%)	683 (31.29)	525 (31.14)	158 (31.79)	0.375 *
Pre-injury SA (Yes), N (%)	507 (22.03)	308 (17.19)	199 (39.10)	<0.001 *
Rehospitalization (Yes), N (%)	594 (26.93)	478 (27.74)	116 (24.02)	0.103 *
TBI severity (Severe), N (%)	1,986 (86.16)	1,550 (86.74)	436 (84.17)	0.136 *
Pre-injury employment (Yes), N (%)	1,597 (76.67)	1,239 (76.53)	358 (77.16)	0.827 *
Year 5				
Covariate	**Total (N=1,843)**	**No SA (n=1,390)**	**SA (n=453)**	**P-value**

Year 1				
Covariate	**Total (N=2,546)**	**No SA (n=2,020)**	**SA (n=526)**	**P-value**
Age, median [IQR]	35 [24-47]	37 [26-47]	28 [22-41]	<0.001 †
Sex (Male), N (%)	1392 (75.53)	1013 (72.88)	379 (83.66)	<0.001 *
ISS, mean ± SD	25.67 ± 11.55	26.21 ± 11.43	25.77 ± 11.85	0.483 †
Employment status at year 1 (Employed), N (%)	544 (34.04)	362 (30.12)	182 (45.96)	<0.001 *
Employment status at year 2 (Employed), N (%)	599 (37.25)	391 (32.15)	208 (53.06)	<0.001 *
Employment status at year 5 (Employed), N (%)	710 (38.65)	475 (34.3)	235 (51.99)	<0.001 *
SA at year 1 (Yes), N (%)	309 (18.78)	131 (10.51)	178 (44.61)	<0.001 *
SA at year 2 (Yes), N (%)	339 (21.16)	142 (11.7)	197 (50.77)	<0.001 *
Marital status (Married), N (%)	622 (33.77)	519 (37.34)	103 (22.79)	<0.001 *
Marital status (Divorced/Widowed), N (%)	347 (18.84)	277 (19.93)	70 (15.49)	<0.001 *
Education (<=11 years), N (%)	531 (31.49)	409 (32.41)	122 (28.77)	0.195 *
Education (‘HS diploma’), N (%)	507 (30.07)	366 (29.00)	141 (33.25)	0.195 *
Pre-injury SA (Yes), N (%)	414 (22.77)	263 (19.16)	151 (33.93)	<0.001 *
Rehospitalization (Yes), N (%)	445 (25.98)	361 (27.81)	84 (20.24)	0.002 *
TBI severity (Severe), N (%)	1,567 (86.29)	1,188 (87.16)	379 (83.66)	0.061 *
Pre-injury employment (Yes), N (%)	1,227 (76.63)	916 (76.59)	311 (76.79)	0.988 *

Column percentages reported

[*] For categorical variables: p-value was calculated using Chi-square test

[†] For continuous variable ‘Age’ p-value was calculated using two-sample Wilcoxon rank-sum (Mann-Whitney) test and for ‘ISS’ p-value was calculated using two-sample T-test

TBI=Traumatic Brain Injury; ISS=Injury Severity Scale; SA=Substance Abuse

Table 2:

Results of Logistic Regression Models

Covariates	Employment			Substance abuse		
	OR	P-value	95% CI of OR	OR	P-value	95% CI of OR-
Year 1	*N=2,189*			*N=2,189*		
Age	0.973	<0.001	[0.962, 0.983]	0.972	<0.001	[0.961, 0.984]
Sex	1.251	0.078	[0.976, 1.606]	1.443	0.011	[1.091, 1.925]
Injury severity scale (ISS)	0.990	0.022	[0.981, 0.999]	0.989	0.027	[0.980, 0.999]
Substance abuse at year 1	1.692	<0.001	[1.308, 2.192]			
Employment at year 1				1.669	<0.001	[1.294, 2.154]
Year 2	*N=1,885*			*N=1,847*		
Age	0.970	<0.001	[0.955, 0.985]	0.981	0.008	[0.968, 0.995]
Sex	1.273	0.189	[0.890, 1.829]	1.510	0.018	[1.080, 2.134]
Injury severity scale (ISS)	1.001	0.829	[0.989, 1.014]	1.001	0.812	[0.990, 1.013]
Employment at year 1	41.018	<0.001	[30.024, 56.77]			
Employment at year 2				1.589	0.003	[1.176, 2.151]
Substance abuse at year 1				9.007	<0.001	[6.841, 11.905]
Substance abuse at year 2	1.139	0.493	[0.783, 1.652]			
Year 5	*N=1,323*			*N=1,285*		
Age	0.954	<0.001	[0.938, 0.970]	0.989	0.159	[0.973, 1.004]
Sex	1.372	0.109	[0.934, 2.024]	1.530	0.030	[1.050, 2.264]
Injury severity scale (ISS)	0.998	0.749	[0.984, 1.012]	1.005	0.422	[0.992, 1.018]
Employment at year 1	3.917	<0.001	[2.583, 5.924]			
Employment at year 2	8.516	<0.001	[5.755, 12.705]			
Employment at year 5				1.584	0.007	[1.133, 2.217]
Substance abuse at year 1				3.149	<0.001	[2.186, 4.531]
Substance abuse at year 2				4.899	<0.001	[3.504, 6.855]
Substance abuse at year 5	1.273	0.215	[0.868, 1.865]			

Abbreviated model presented. Logistic regression was controlled for marital status, education, pre-injury drug use, post-injury rehospitalization, TBI severity, and pre-injury employment

CI=Confidence Interval; ISS=Injury Severity Scale; OR=Odds Ratio; SA=Substance Abuse; TBI=Traumatic Brain Injury