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ORIGINAL PAPER

Traumatic brain injury as an independent risk factor for problem gambling: a matched case-control study

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Abstract

Purpose To assess whether traumatic brain injury (TBI) increases the risks of subsequent problem gambling.

Methods We conducted a matched case–control analysis of adults in Ontario, Canada. The study included those who self-reported their gambling activities in the Canadian Community Health Survey 2007–2008. Using Problem Gambling Severity Index, we defined cases as those who were problem gamblers and controls who were recreational gamblers. Cases were matched to controls 1:2 using propensity scores based on demographics, prior mental health, and self-reported behaviours. The main predictor was prior TBI defined as requiring emergency care and identified using ICD-10 codes from administrative health databases. We estimated the likelihood of prior TBI in problem gamblers compared to controls using conditional logistic regression.

Results Of 30,652 survey participants, 16,002 (53%) reported gambling activity of whom 14,910 (49%) were recreational gamblers and 4% ($n = 1092$) were problem gamblers. A total of 1469 respondents (5%) had a prior TBI. Propensity score matching yielded 2038 matched pairs with 1019 cases matched to 2037 controls. Case–control analysis showed a significant association between prior TBI and subsequent problem gambling (odds ratio 1.27, 95% confidence interval 1.07–1.51, $P = 0.007$). The increased risk was mostly apparent in men aged 35 to 64 years who reported alcohol use or smoking. The relative risk of problem gambling in those with two or more TBIs equated to an odds ratio of 2.04 (95% confidence interval 1.05–3.99).

Conclusions We found that a prior TBI was associated with an increased subsequent risk of problem gambling. Our findings support more awareness, screening, and treating problem gambling risks among TBI patients.

Keywords Concussion · Head injury · Pathological gambling

Introduction

Traumatic brain injury (TBI) is a global health problem gaining greater recognition worldwide [1]. In the United States alone, TBI accounts for nearly 50,000 deaths each year [2]. The healthcare burdens of non-fatal TBI are also substantial and lead to more than 2.5 million physician visits including 280,000 hospitalizations costing over 76 billion dollars to the United States economy [3]. The full consequences of TBI is further increased by long-term complications such as severe neuropsychiatric conditions and cognitive deficits requiring chronic care [4].

Most TBI patients fully recover from their injuries, yet a significant proportion show some cognitive changes including impulsivity, affective instability, lack of awareness, or apathy [5]. Some studies suggest that TBI might exacerbate substance addiction [6, 7]. For instance, a study showed a threefold increase in addictive disorders among United States Air Force members after suffering a mild TBI [8]. Similarly, a Canadian cross-sectional design study showed a nearly twice fold increase in substance misuse in participants reporting a TBI [7]. These findings may be explained by potential impact of TBI on mesolimbic dopaminergic

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pathways linked with addictive disorders [9, 10]; nonetheless, the putative mechanisms of underlying consequences remain elusive [6, 11].

Recreational gambling is frequent in Western societies [12–15]. For example, in Ontario, Canada, several surveys indicated the prevalence of recreational gambling during the past 1 year to be as high as 60–80% among adults [16, 17]. The high prevalence can be linked to the growth in venues over the past three decades in Canada [18, 19]. In some gamblers (1–5%), this recreational activity leads to negative consequences on psychosocial health, often known as problem gambling [20, 21]. For Ontario, these estimates translate to about 332,000 adults experiencing problem gambling [22]. Risk factors for problem gambling include younger age [14], male sex [12, 14], and a history of mental health problems (substance misuse, self-harm, mood disorders) [23, 24]. Problem gambling has recently been classified as an addictive disorder because evidence suggests similar activation of brain reward centres in problem gamblers as observed in those with substance addiction [25].

Interestingly, several studies on TBI patients describe increased risky decision-making as ascertained by gambling contingencies in neurocognitive tasks [26–29]. Since TBI might lead to addiction, therefore, several explorations on whether TBI increases risky gambling practices have been initiated [30, 31]. Nonetheless, studies of gambling risks following TBI are inconclusive and had limited information on gambling behaviours or the TBIs in specific samples [8, 31]. To further explicate the relationship between TBI and problem gambling, we sought to overcome the limitations of previous work using a large population-based cohort.

Methods

Setting and design

We conducted a matched case–control analysis of a sample of adults included in large population-based administrative datasets in Ontario, Canada. Ontario is the most populous province of Canada with a population of approximately 11 million persons during 2007–2008 [32]. Ontario has a public-funded, comprehensive healthcare system with no user fees and universal access [33]. These datasets also include individual diagnoses coded using the International Classification of Disease Codes (ICD) 9 and 10 [34]. In 2007–2008, a representative sample of adults participated in the Canadian Community Health Survey (CCHS) including a detailed questionnaire, the Problem Gambling Severity Index (PGSI) [35, 36]. The PGSI was not repeated in subsequent cycles of CCHS, and therefore, CCHS 2007–2008 was used to define our main outcome variable.

The study methods were approved by the Privacy Impact Services, Institute for clinical evaluative sciences (ICES) and the Research Ethics Board of the Sunnybrook Health Sciences Centre, both located in Toronto, ON, Canada.

Study population

The CCHS was a cross-sectional survey covering approximately 98% of Canadian population aged 12 years or older. The study sample included adult respondents from the province of Ontario who were 18 years or older on the survey response date. Persons living on reserves and other aboriginal settlements, full-time members of the Canadian Forces, and the institutionalized populations in Ontario were excluded. Data are collected directly from participants using the computer assisted interviewing either in person or by phone. Responding to the survey was voluntary.

Cases and controls

For this study, cases were respondents for whom the PGSI survey indicated problem gambling (see below). Controls were respondents for whom the PGSI indicated active recreational gambling. Survey respondents were linked to prior administrative healthcare data, thus allowing the proposed analyses. We confirmed the residence status following the survey response using a vital statistics registry [34]. We selected controls from recreational gamblers because of the high prevalence of such individuals (up to 80%) in Ontario [16, 17, 19]. Non-gamblers were excluded from the main analysis.

Measures and databases

Gambling The Problem Gambling Severity Index (PGSI) was used to distinguish problem gamblers from other active gamblers. The PGSI has been previously used to assess the association of problem gambling with health outcomes [20, 37]. All PGSI questions were asked with respect to a timeline of 12 months prior to the survey date [38]. The PGSI is a nine-item tool that assessed gambling severity on a scale ranging from 0 to 27 and it categorizes individuals as non-gamblers, no-risk or recreational gamblers, and risky gamblers (who were further classified as low-, moderate, or high-risk) [39]. Risky gambling of any severity was considered as problem gambling. In a representative sample of recreational and problem gamblers, the PGSI showed high internal consistency (Cronbach's alpha = 0.84) as well as high diagnostic accuracy (area under curve = 0.98, $P < 0.001$) when validated with in-depth clinical assessments by three psychologists [40].

Traumatic brain injury We used the National Ambulatory Care Reporting System (NACRS) to identify a prior

TBI diagnosis. NACRS encompasses all emergency department visits in the region. The study had access to NACRS datasets from April 1, 2002 to March 31, 2014. We identified TBI cases from any emergency visit using the Centers for Disease Control and Prevention (CDC) recommended ICD-10 codes: S01.0-S01.9; S02.0, S02.1, S02.3; S02.7-S02.9; S04.0; S06.0-S06.9; S07.0; S07.1; S07.8; S07.9; S09.7- S09.9;T01.0; T02.0; T04.0; T06.0; T90.1; T90.2; T90.4; T90.5; T90.8; T90.9 [41]. To date, the CDC proposed classification remains the most comprehensive for studying TBI [42]. This classification excluded superficial injuries, dislocations, sprains, and injuries to eyes and orbit. The maximum look-back period for identifying a prior TBI was April 1, 2002 because this date marked the start of NACRS reporting. Only a TBI prior to the survey response was considered as potential predictor.

Confounders From the survey, we extracted information about other important risk factors for problem gambling including self-reported lifetime alcohol use, smoking, and suicide attempts. We also used administrative datasets to extract information about socioeconomic status and prior diagnosis of mental health conditions including depression, anxiety, and alcohol dependence [43].

Statistical analysis

For descriptive proposes, we tested using Chi square test whether the presence of a prior TBI was significantly more common in different in groups, e.g., non-gamblers, recreational gamblers, and problem gamblers. We also assessed whether gambling status was associated with subsequent traumatic brain injuries recorded up to March 31, 2014 following the survey response date. We then used propensity scores estimated from multivariate logistic regression to match each problem gambler (cases) to two controls selected from recreational gamblers. The propensity scores were based on demographics (age, sex, and socioeconomic status), prior mental health (alcoholism, depression, and anxiety), and aforementioned behaviours (alcohol use, smoking, and suicide attempts). The matching process had 1:2 greedy nearest neighbors matching within propensity score calipers of ± 0.2 standard deviations (SD) and with replacement. After matching, we conducted a univariate analysis (conditional logistic regression) to assess whether the distribution of potential confounders was equal in both the groups. Finally, we conducted a conditional logistic regression with problem gambling as the main dependent variable and prior TBI as the main predictor variable. The estimated odds ratio represented the association of prior TBI with problem gambling. We conducted sensitivity analysis for different subgroups based on age, gender, prior medical history (e.g., alcohol dependence), and aforementioned risk behaviours (e.g., alcohol use yes/no) to assess if the association was more pronounced in any strata. We also conducted an analysis with TBI frequency as the main predictor classified in a binary manner as either one prior TBI or multiple prior TBI events.

We conducted additional analyses due to concerns about using propensity score matching [44]. In particular, we repeated the analyses using the conventional exact matching with the same variables used for matching problem gamblers with non-gamblers as were in the propensity score matching. In addition, we also conducted a separate, similar analysis with problem gamblers as cases and non-gamblers as controls matched using propensity scores to assess if similar results were obtained.

Results

Information about gambling status was ascertained from 30,652 adult respondents, of whom 16,002 (53%) self-identified as active gamblers including 14,910 (49%) as recreational gamblers and 1092 (4%) as problem gamblers (Table 1). A total of 1469 (5%) respondents had a TBI prior to survey date during a mean interval of 2.9 years (standard deviation = 1.7). Of these, 146 individuals (0.5%) had multiple TBI incidents.

Those who had a prior TBI were significantly more likely to report problem gambling ($n = 79$, 5.4%) as compared to those who had not suffered a TBI ($n = 1013$, 3.5%). Those who had a prior TBI were also more likely to report going back to try to win back losses (7.3% vs. 5.0%, $P = 0.02$) and bet more than they can afford (5.8% vs. 3.7%, $P = 0.02$) as compared to those who had not suffered a TBI. Similarly, as compared to those who had not suffered a TBI, those who had a prior TBI were more likely to be men (57.7% vs. 44.2%, $P < 0.001$), younger than 25 years (19.6% vs. 8.2%, $P < 0.001$), hold the lowest socioeconomic status (25.3% vs. 19.5%, $P < 0.001$), report smoking (55.4% vs. 52.7%, $P = 0.04$), have attempted suicide (1.4% vs. 0.6%, $P < 0.001$), been diagnosed with alcohol dependence (15.9% vs. 10.8%, $P < 0.001$), or been diagnosed with depression (18.4% vs. 12.7%, $P < 0.001$).

Prior to the propensity score matching, we confirmed the direction of association by comparing gambling status between those who suffered a TBI prior to gambling status and those who suffered after the report up to March 31, 2014. We found that gambling status was not associated with subsequent TBIs (data not shown). We also assessed if severe TBIs prior to 2002 reported in other health datasets were associated with problem gambling, and we found findings consistent with above direction of associations (data not shown).

The propensity score matching of 1:2 yielded a total of 2038 matched pairs that had 2037 controls matched to 1019

Table 1 Prevalence of Prior Traumatic Brain Injuries in the Canadian Community Health Survey 2007–2008 respondents ($n = 30{,}652$)

	No Prior TBI ($n = 29{,}183$, 95.2%)		Prior TBI ($n = 1469$, 4.8%)		*P*
	n	%	*n*	%	
Problem Gambling Severity Index (PGSI)					< 0.001
Non-gambler	13,987	47.9	663	45.1	
Recreational gambler	14,183	48.6	727	49.6	
Problem gambler	1013	3.5	79	5.4	
Individual items of PGSI (yes/no)[a]					
Bet larger amounts for excitement	294	3.5	19	4.1	0.46
Went back to try	416	5.0	34	7.3	0.02
Felt that there is a problem	242	2.8	7	1.5	0.09
Criticized by others	250	2.9	11	2.4	0.47
Felt guilty	452	5.3	27	5.8	0.63
Bet more than can afford	309	3.7	27	5.8	0.02
Sex					< 0.001
Women	16,275	55.8	847	42.3	
Men	12,908	44.2	333	57.7	
Age (in years)					< 0.001
18–24	2389	8.2	288	19.6	
25–34	4025	13.8	225	15.3	
35–65	15,262	52.3	610	41.5	
65 and above	7507	25.7	346	33.6	
Income status					< 0.001
Lowest	5181	19.5	333	25.3	
Next lower	5103	19.2	227	17.2	
Middle	5467	20.6	254	19.3	
Next higher	5167	19.4	254	19.3	
Highest	5659	21.3	251	19.0	
Risky behaviours					
Smoking	15,392	52.7	814	55.4	0.04
Alcohol use	23,739	81.4	1214	82.6	0.21
Suicide attempt	165	0.6	20	1.4	< 0.001
Mental health diagnosis[a]					
Alcohol dependence	3143	10.8	233	15.9	< 0.001
Depression	3709	12.7	270	18.4	< 0.001
Anxiety	17,196	58.9	877	59.7	0.55

[a]Items are inspired from Diagnostic Statistical Manual Version IV

cases (Table 2). The univariate analysis indicated that the propensity score matching was successful as all variables were similarly distributed between cases and controls. As anticipated, the univariate analysis showed that problem gamblers were significantly more likely to have had a prior TBI than recreational gamblers (7% vs. 5%, $P = 0.03$).

The increased likelihood of a prior TBI in problem gamblers as compared to recreational gamblers equalled an odds ratio (OR) of 1.27 (95% Confidence Interval [CI] 1.07–1.51) (Table 3). Sensitivity analyses indicated the association persisted for those who were men (OR 1.29, 95% CI 1.05–1.60), aged 35–64 years (OR 1.36, 95% CI 1.04–1.79), reported smoking (OR 1.28, 95% CI 1.03–1.59) or reported alcohol use (OR 1.34, 95% CI 1.12–1.61). The relative risk of problem gambling in those with multiple TBI emergencies equated to an odds ratio of 2.04 (95% CI 1.05–3.99).

In addition, a re-analysis using exact matching methods for all covariates yielded an odds ratio of 1.29 (95% CI 1.07–1.57) for problem gambling in TBI patients as compared to recreational gamblers. In a separate comparison using similar methods while matching problem gamblers ($n = 1019$) with non-gamblers ($n = 2038$), the relative risk of TBI were significantly higher in problem gamblers as compared to non-gamblers (OR 1.24, 95% CI 1.04–1.47).

Table 2 Characteristics of 1:2 matched sample of problem gamblers and recreational gamblers

	Recreational gamblers ($n=2037$)		Problem gamblers ($n=1019$)		*P*
	n	%	*n*	%	
Prior TBI					0.03
No	1928	94.7	944	92.6	
Yes	109	5.4	75	7.4	
TBI events requiring care					0.03
Single	101	5.0	65	6.4	
Multiple	8	0.4	10	1.0	
Sex					0.93
Women	874	42.9	439	43.1	
Men	1163	57.1	580	56.9	
Age (in years)					0.92
18–24	190	9.3	102	10.0	
25–34	334	16.4	168	16.5	
35–64	1136	55.8	558	54.8	
65 and above	377	18.5	191	18.7	
Risky behaviours					
Smoking	1351	66.3	669	65.7	0.71
Alcohol use	1767	86.8	887	87.1	0.81
Suicide attempt	21	1.0	14	1.4	0.41
Mental health diagnosis[a]					
Alcohol dependence	357	17.5	182	17.9	0.81
Depression	330	16.2	161	15.8	0.77
Anxiety	1283	63.0	644	63.2	0.91

[a]Based on ICD 9 diagnostic codes for alcohol dependence (ICD 9 codes 303, 304, 305), anxiety (ICD 9 code 300), and depression (ICD 9 code 311)

Table 3 Likelihood of traumatic brain injury (TBI) in problem gamblers compared to recreational gamblers

	Likelihood of TBI in problem gamblers	
	Odds ratio	95% confidence interval
Total	1.27	1.07–1.51
Sex		
Women	1.23	0.90–1.67
Men	1.29	1.05–1.60
Age (in years)		
18–24	1.14	0.79–1.65
25–34	1.25	0.82–1.90
35–64	1.36	1.04–1.79
65 and above	1.24	0.82–1.88
Risky behaviours		
Smoking	1.28	1.03–1.59
Alcohol use	1.34	1.12–1.61
Suicide attempt	1.03	0.59–1.78
Mental health diagnosis[a]		
Alcohol dependence	1.36	0.92–2.00
Depression	1.02	0.69–1.51
Anxiety	1.20	0.96–1.49
TBI events requiring care (reference: no injury)		
Single	1.21	1.01–1.44
Multiple	2.04	1.05–3.99

[a]Based on ICD 9 diagnostic codes for alcohol dependence (ICD 9 codes 303, 304, 305), anxiety (ICD 9 code 300), and depression (ICD 9 code 311)

Discussion

We investigated whether a prior TBI diagnosis was an independent predictor of problem gambling using a propensity score-matched case–control design. Our findings suggested that problem gamblers are more likely to have suffered a prior TBI than active recreational gamblers, equating to a 27% increased odds. These findings persisted for different patient sub-groups including in middle-aged men with current alcohol use or smoking. Having more than one previous TBI diagnosis led to an approximate doubling of the risk of problem gambling.

Our study has several limitations. Firstly, our definition of a prior TBI diagnosis was based on ICD-10 codes years earlier without severity information such as the Glasgow Coma Scale [45]. The emergency data indicated that nearly 19 out of 20 patients were not hospitalized for the TBI and suggested that most of the identified injuries were of mild severity [46]. It is possible that using ICD 10 codes might have misclassified a proportion of patients as suffering from TBI or otherwise. There have been no validation studies for TBI diagnoses in the available healthcare administrative datasets though these sources had been used in the past to assess risk factors for TBI [47, 48].

In addition, the main outcome variable was based on self-report and, therefore, the possibility of social desirability bias could attenuate our findings [46]. While we adjusted the analysis for available confounders, many factors such as drug misuse could not be accounted in our analysis [49]. Lastly, propensity score matching could still result in imbalances and statistical bias from associations of covariates during score estimations [50]. Nevertheless, our re-analysis using exact matching methods showed similar results as per our primary approach.

The findings of this study suggest that problem gambling might sometimes be a long-term neurobehavioral sequela of a past TBI. This finding supports past work that TBI might lead to changes in executive functioning such as problem solving, set-shifting, impulse control, and self-monitoring [26, 51]. An alternate interpretation is that those prone to TBI are also prone to problem gambling. Our finding suggests a real world implication of deficits in gambling contingencies-based tasks in TBI patients as reported in past work [26, 30]. The putative mechanisms of such changes following a TBI remain to be clarified.

Consistent with some other studies, our findings suggest that a TBI might theoretically affect brain reward mechanisms linked to addictive disorders [5]. Several studies indicate that these abnormalities can mediate harmful behaviours like drunk driving or self-harm emergencies [52, 53]. For example, a large study of veterans showed that mild to moderate TBI increased the risks of subsequent addictions-related discharge from the military service [54]. Taken together, our findings support that adverse long-term neurobehavioral consequences of a prior TBI might share some commonalities that could point toward specific treatment options [55].

About 5% of our sample suffered a TBI during an average interval of 6 years. These rates were similar to estimates from other surveys [56, 57]. We also found that middle-aged men were more likely to manifest the association of TBI with problem gambling and that the association remained consistent in sub-groups who had a history of smoking and alcohol use. Our findings further suggest a dose–effect as shown by an accentuated relative risk of problem gambling with multiple prior TBI emergencies. Overall, these findings indicated that TBI might predict future problem gambling.

In conclusion, our study suggests that TBI might subsequently increase the risks of problem gambling. Our findings support screening and counselling of TBI patients for such potential consequences. The feasibility of screening problem gambling risks in TBI patients remains to be assessed however. Finally, these findings provide impetus to explore further the associations of problem gambling with TBI and the underlying mechanisms of these associations.

Authors' contributions JAB, DT, and DAR had full access to the data and take responsibility for accuracy of data analysis. Study concept and design: All authors. Acquisition, analysis, or interpretation of data: All authors. Drafting of manuscript: JAB, DAR Statistical analysis: JAB, DT, DAR, Administrative support, obtained funding and supervision: Redelmeier.

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Compliance with ethical standards

Conflict of interest No conflicts of interests were identified for any of the authors.

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Data sharing statement No additional data available.

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