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The association of co-occurring alcohol misuse and traumatic brain injury on mental health and conduct problems in adolescents.

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ABSTRACT

Objective: This study describes the impact of traumatic brain injury (TBI) and hazardous drinking on mental health and behavioral issues among Ontario adolescents. In particular, we assessed the incremental co-occurrence of hazardous drinking with history of TBI, in comparison to experiencing just one of these conditions.

Method: A cross-sectional subsample of 3130 Ontario adolescents attending grades 9 through 12, were surveyed in 2013 as part of the Centre for Addiction and Mental Health's Ontario Student Drug Use and Health Survey. *Recent* (past year) and *former* (lifetime, excluding last year) TBI were defined as trauma to the head that resulted in loss of consciousness for at least five minutes or overnight hospitalization. Current hazardous drinking was derived using the Alcohol Use Disorders Identification Test (AUDIT).

Results: An estimated 11.8% (95% CI: 10.1, 13.8) reported a history of *former* TBI and were not hazardous drinkers; 4.0% (95% CI: 2.9, 5.5) reported *recent* TBI and were not hazardous drinkers; 13.7% (95% CI: 12.3, 15.3) were hazardous drinkers who never had a TBI; 4.1% (95% CI: 2.9, 5.8) had *former* TBI with co-occurring hazardous drinking; and 2.2% (95% CI: 1.6, 3.0) had *recent* TBI with co-occurring hazardous drinking. Most odds increased significantly and were between 2 to 3 times higher for reporting compromised mental health, violent and non violent conduct behaviors, and reported victimization for classifying as hazardous drinker at the time of testing with co-occurring either *former* or *recent* TBI compared to classifying as not having either of these conditions. Adolescents classified as hazardous drinkers with *former* TBI had

numerous and higher odd ratios for conduct behaviors than hazardous drinkers with *recent* TBI.

Conclusion: Results emphasize the strong interplay between TBI and hazardous drinking, and point to the need for integrating prevention efforts to reduce these conditions and their co-occurrence among adolescents.

ARTICLE SUMMARY

Strengths and limitations of this study:

- The study shows that the emergence of hazardous drinking over the high school years may occur at an elevated rate among adolescents with traumatic brain injury (TBI).
- This is the first time when temporarily interpretable patterns of association between hazardous drinking and history of TBI among adolescents were examined in the context of co-occurring mental health and problem behaviours in a population based study.
- Adolescents who classified as hazardous drinkers at the time of testing, with *former* lifetime history of TBI (that occurred prior to past 12 months), had numerous and higher odd ratios for conduct behaviors than hazardous drinkers with r*ecent* TBI (that occurred in the past 12 months).
- Hazardous drinkers with *recent TBI* had more and higher odd ratios for most mental health behaviors than hazardous drinkers with *former TBI*.
- These results demonstrate that whether the TBI occurred recently (past year) or previously (prior to last year) may be an important consideration for

management for these conditions and rehabilitation efforts.

- Possible bias related to self-report procedures and the preclusion of causal inferences due to the cross-sectional nature of the data are limitations of this study.
- Even though our data did not present evidence of appreciable bias overall, nonresponse bias may exist.

KEYWORDS: Traumatic brain injury, hazardous drinking, mental health, violence, adolescents

Introduction

Excessive drinking in adolescence can cause substantial harm to individuals, and is associated with future alcohol-related problems.[1-3] Drinking in adolescence is particularly risky because it is much more likely to be heavy and episodic (binge).[4-5] Excessive drinking during adolescence, while the brain is still developing, can be a major cause of trauma, physical injuries, hospitalization, prolonged disability and premature death.[1-3,6] Alcohol contributes substantially to motor vehicle collisions, homicides, suicide, assault, sexual risk-taking, and many other problems in Canada and the US.[7-16]

Hazardous drinking is both a contributor to and a consequence of traumatic brain injury (TBI).[17-18] Traumatic brain injuries (TBI) occur when a sudden trauma (hit or blow to the head) causes damage to the brain. An estimated one in 5 adolescents in Ontario has experienced TBI in their lifetime, and one in 18 has experienced it during the past 12 months.[19-20] Hospitalization data revealed that almost half of the individuals presenting with brain injuries were intoxicated upon hospital admission, and among adolescents and adults who required inpatient rehabilitation post TBI, over 60% were found to have had a history of alcohol or other drug misuse.[21-23] Adolescents who had experienced one or more TBIs in their lifetime had odds twice as much, to screen positive for current hazardous drinking or for reporting binge drinking in the past 12 months, compared to those who never had a TBI.[20]

Both TBI and hazardous drinking are relatively common among adolescents[4,19,20] and both have been linked with poor academic performance, mental health issues including suicide, and increased violent and non-violent conduct

behaviors.[19,24-29] Several studies using imaging methods have noted negative additive effects of alcohol misuse and TBI, such as brain atrophy over time and reduced reaction times.[30-32] However, no studies have compared the separate and joined effects of hazardous drinking and TBI in general population or clinical samples of adolescents. Specifically, although previous research shows that both hazardous drinking and a history of TBI are associated with harmful health outcomes, that include mental health and behavioral issues, the incremental impact of having both of these conditions is unknown.[4,19-20,25-32] This study examines the association of history of TBI and hazardous drinking, separately and jointly, with past year mental health and conduct behaviors in a large representative sample of high school adolescents, in Ontario.

Methods

Data were based on a subsample of 3264 students in grades 9 to 12 and were derived from the 2013th cycle of the Centre for Addition and Mental Health's (CAMH) Ontario Student Drug Use and Health Survey (OSDUHS), a biennially repeated cross-sectional probability survey of Ontario students enrolled in four provincially-funded jurisdictions (Public vs. Catholic; English vs. French). In 2013, students were recruited from 198 schools and 671 classes dispersed province wide. Schools excluded from sampling were private, military, and institutional schools. With these exclusions our sample captures 92% of all Ontario children and adolescents aged 12 to 18.

Students completed self-administered, anonymous pen-and-paper questionnaires in their classrooms between November 2012 and June 2013. Participation rates were 61% for schools, 87% for classes, and 63% for students. A comparison between high (≥ 70%) and low responding classes showed no evidence of nonresponse bias for a number

of health-relate behaviours including TBI and the AUDIT.[4] Students completed one of two questionnaires (Form A or Form B) alternately distributed (i.e., A, B, A) within each class. Although the TBI items were asked of all students using forms A and B, because the AUDIT screener was contained in form A only, the estimation samples were reduced from 6159 to 3264 students. Detailed description of the sampling design and survey procedures is web-available.[4] The study was approved by the Research Ethics Committees of the Centre for Addiction and Mental Health (CAMH), St. Michael's Hospital (SMH), participating Ontario Public and Catholic school boards, and York University, which administered the surveys. All participants provided their assent in addition to parentally signed consent for those aged under 18.

Measures

Group membership categorization.

Our key analytical measure was derived from hazardous drinking and history of TBI. Hazardous or harmful drinking was derived using the 10-item AUDIT screener, a well-validated instrument assessing drinking frequency, volume, heavy consumption and indicators of abuse and dependence due to alcohol.[33] A cut score at or above 8 of 40 indicates a pattern of hazardous or harmful drinking.[34]

Traumatic brain injury (TBI) was based on two questions that asked students if they ever had a blow or a hit to the head that rendered them unconscious for at least five minutes or resulted in their hospitalization for at least one night. This criteria is also employed in diagnostic classification systems including DSM-IV and has previously been used in adolescent and adult studies.[35] Students were then asked if they ever had such injury in the 12 months prior (recent TBI) or in their lifetime, but not in the 12

months prior (former TBI). Our analytic variable was formed by cross-tabulating these two measures to create out a 6-class membership variable.

The first set of analyses (Tables 2 through 4) were based on the following 6 classifications. The baseline classification included adolescents who never had a TBI and screened negative for hazardous drinking on the AUDIT at the time of testing. The second classification included adolescents with *former TBI* (experienced sometimes during their lifetime but not in past 12 months) and were not hazardous drinkers. Members in the third classification included adolescents with *recent TBI* (experienced in the past 12 months) and were not hazardous drinker. The fourth classification included adolescents who screened positive on the AUDIT at the time of testing (hazardous drinkers) but did not report TBI (*no former or recent*). The fifth classification included current hazardous drinkers with co-occurring *former TBI*, and the six classification included hazardous drinkers with co-occurring *recent TBI* (no *former TBI*). The second set of analyses (Table 5) were based on the following 3 classifications: adolescents who did not report a TBI (former or recent) nor did they screen positive on the AUDIT; adolescents who reported either former or recent TBI, or who screened positive on the AUDIT; and adolescents who screened positive on the AUDIT and also reported either former or recent TBI. Mental health problems, conduct behaviors and covariates are summarized in Table 1.

Analysis

Data derived from complex surveys using stratification and clustering fail the assumption of independent observations and thus underestimate variances (and in doing they overstate significance levels resulting in false positive inferences). We therefore

employed design-based estimation methods to accommodate such violations. Our subsample analyses utilized a complex sample design with 20 strata (region by school level), and 198 primary sampling units (high schools). The variance of our analyses was estimated by Taylor Series Linearization (TSL) executed in the Complex Sample module in SPSS version 23.0 (SPSS Inc., 2015). In addition to strata and clusters, our analyses employed case weights that factored inclusion probabilities, nonresponse and post stratification adjustments. We applied multinomial logistic regressions to assess the association between TBI-AUDIT classes with the 8 mental health, and 15 conduct behaviors, with and without holding sex and grade constant, against $P < 0.05$ (two-tailed). The results are based on 'valid' responses (n's); missing data (i.e. 'don't know' responses and refusals) were excluded. Listwise deletion reduced the estimation sample from 3264 to 3130.

Results

An estimated 11.8% (95% CI: 10.1, 13.8) of Ontario adolescents reported *former TBI*, 4.0% (95% CI: 2.9, 5.5) reported recent TBI, 13.7% (95% CI: 12.3, 15.3) were identified as hazardous drinkers, 4.1% (95% CI: 2.9, 5.8) reported *former TBI* with co-occurring hazardous drinking, 2.2% (95% CI: 1.6, 3.0) reported *recent TBI* with co-occurring hazardous drinking, and 64.1% (95% CI: 60.9, 67.2) were individuals who never had a TBI and scored negative on the AUDIT.

Table 2 presents the demographic characteristics of the sample by TBI-AUDIT classifications. Odds ratios were similar for males versus females on all 6 TBI-AUDIT classifications, while grade level in high-school significantly predicted TBI-AUDIT classification. Among adolescents in grade 12, odds ratios were 6 times significantly

higher for hazardous drinking, nearly 12 times higher for reporting *former TBI* with co-occurring hazardous drinking, and 3 times higher for reporting *recent TBI* with co-occurring hazardous drinking, compared to baseline classification (neither conditions). Adolescents in grade 11 had odds nearly 4 times higher for hazardous drinking, and nearly 8 times higher for reporting *former TBI* with co-occurring hazardous drinking, compared to baseline classification. Among students in grade 10 the odds were 3 times higher for reporting *former TBI* with co-occurring hazardous drinking, compared to baseline classification.

Table 3 shows the results of multinomial regression analyses fitting TBI-AUDIT classification by mental health conditions. For 5 of the 8 mental health conditions, adjusted odds ratios associated with screening positive for hazardous drinking, without co-occurring history of TBI, were statistically significant, compared to individuals in the baseline classification (neither conditions) and ranged from 1.40 to 6.45. For 6 of the 8 mental health conditions assessed, adjusted odds ratios associated with *former TBI*, without co-occurring hazardous drinking, were statistically significant and ranged from 1.61 to 4.81. Only one of the 8 mental health conditions assessed had significant adjusted odds ratios associated with *recent TBI*. Adjusted odds were 9.14 times higher for suicide attempt among adolescents with *recent TBI* compared to those with no history of TBI that screened negative for hazardous drinking.

With the addition of hazardous drinking to *former TBI*, the adjusted odds ratios associated with 7 of 8 mental health conditions assessed increased, compared to either classification alone, and were statistically significant ranging from 3.75 to 9.70. With the addition of hazardous drinking to *recent TBI*, the adjusted odds-ratios associated

with 7 of the 8 mental health conditions assessed increased, compared to either classification alone, and were statistically significant, ranging from 2.36 to 31.23. Self rated general health was not statistically significantly associated with any of the TBI-AUDIT classifications.

Table 4 shows the results of multinomial regression predicting membership in the 6 TBI-AUDIT classifications by 15 conduct behaviors. For 5 of 12 perpetrator behaviors, statistically significant adjusted odds ratios were associated with *former TBI* compared to the baseline classification (neither conditions). With the addition of hazardous drinking to *former TBI*, the adjusted odds-ratios associated with perpetrator reports of conduct behavior were higher and statistically significant on all 12 measures and ranged between 5.24 and 29.71. For all of the conduct behaviors in which the adolescent reported being a victim, adjusted odds ratios associated with *former TBI*, without hazardous drinking, were statistically significant and ranged between 1.56 and 2.61. With the addition of hazardous drinking to *former TBI*, compared to the baseline classification, the adjusted odds-ratios associated with all 3 conduct behavior victimization variables were statistically significant and ranged between 3.17 and 7.97.

For 9 of the 12 perpetrator type conduct behaviors assessed, statistically significant adjusted odds ratios associated with *recent TBI* classification were observed. For all 3 victimization conduct behaviors associated with *recent TBI* adjusted odds ratios were significant. With the addition of current hazardous drinking to recent TBI, the adjusted odds-ratios associated with perpetrator reports of conduct behavior were statistically significant on 10 of the 13 measures compared to individuals in the baseline membership class (neither conditions). With the addition of hazardous drinking to

recent TBI, compared to the baseline classification , the adjusted odds-ratios associated with all 3 measures of conduct behavior victimization were statistically significant. The adjusted odd ratios of perpetration of conduct behaviors associated with hazardous drinking was statistically significant for all of the 12 measures.

Table 5 summarizes analyses designed to highlight the incremental impact of experiencing co-occurring TBI and hazardous drinking compared to either condition by itself (referent). The analysis also included those with no history of TBI or hazardous drinking. Comparisons between the three groups revealed significantly higher adjusted odds ratios that ranged between 2.17 to 2.98 on all 6 mental health measures for students who experienced both conditions in comparison to those who experienced one. Students who reported both conditions (TBI and co-occurring hazardous drinking) had significantly higher adjusted odds of mental health problem indicators on measures of psychological distress, use of medication for depression or anxiety, contemplating suicide in the past 12 months, attempting suicide in the past 12 months, and fair or poor self-reported mental health. The two groups did not differ on three mental health measures (called a crisis or help line, used prescribed medication for ADHD, reporting fair or poor general health). Compared to students who experienced one condition (had history of TBI or screened positive for hazardous drinking), students reporting neither had significantly lower adjusted odds of mental health problem indicators on seven of the eight measures. The only exception was that the groups did not differ on self-reported general health.

For measures of perpetration (Table 5), students who reported co-occurring TBI and hazardous drinking had significantly higher adjusted odds of reporting taking a car

without permission, damaging property, selling cannabis, stealing more than $50, beating up or hurting someone, breaking into a locked building, carrying a weapon, setting a fire, fighting on school property, and bullying others at school. The two groups did not differ on the adjusted odds of taking things worth less than $50 and running away from home. Compared to the group reporting one condition (TBI or hazardous drinking), those reporting neither had significantly lower adjusted odds on all measures of perpetration. For measures of victimization, those reporting both conditions (TBI and co-occurring hazardous drinking) had significantly higher adjusted odds of being threatened with a weapon and being bullied on the internet, but did not differ on odds of being bullied at school. Those reporting neither conditions (never had TBI and failed to score positive for hazardous drinking), compared to the group reporting one of the two conditions (TBI or hazardous drinking), had significantly lower adjusted odds on all three measures of victimization.

Discussion

In this population of Ontario high school students, one in eight reported *former TBI* (incurred during lifetime but not in the past 12 months) and were not current drinkers; one in 25 were identified as hazardous drinkers with co-occurring recent TBI; one in 7 were identified as hazardous drinkers and had no history of TBI; one in 24 were identified as hazardous drinkers with co-occurring history of former TBI; and one in 45 were identified as hazardous drinkers with co-occurring recent TBI. In our sample, group membership did not vary by sex, but did vary by age, as measured by school grade. Significant odds ratios emerged for hazardous drinking with co-occurring history of former TBI among grade 10, 11 and 12 students compared to those in grade 9. Odds

ratios were three times higher for hazardous drinking with co-occurring recent TBI among grade 12 compared to grade 9 students. Odds ratios were 3.5 and 6 times higher for hazardous drinking among grade 11 and 12 students, respectively, compared to grade 9 students. These differences mirror patterns of such differences in the adolescent population reported previously.[4,18-21,35] These results show the emergence of hazardous drinking over the high school years, and suggest that this emergence may occur at an elevated rate among those with former and current TBI.

Since we were unable to find previous studies examining the co-occurrence of hazardous drinking and TBI in a representative sample of adolescents, there is no study to compare our estimates. However, adult studies have shown that among individuals currently in rehabilitation for substance abuse the rates of co-occurring history of TBI ranged between 38% to 63%.[36-37] We found that of all students screening positive at the time of testing for hazardous drinking, 32.4% also reported a history of TBI, which approaches the range observed in these adult studies, and confirms the notable existence of the TBI-alcohol co-occurrence.

Adolescents who classified as hazardous drinkers with *former TBI* had numerous and higher odd ratios for conduct behaviors than hazardous drinkers with *recent TBI*. Furthermore, hazardous drinkers with *recent TBI* had more and higher odd ratios for most mental health behaviors than hazardous drinkers with *former TBI*. To our knowledge this is the first time when temporarily interpretable patterns of association such as these have been demonstrated in a population based study. These results demonstrate that whether the TBI occurred recently (past year) or previously (prior to last year) may be an important consideration for management for these conditions and

rehabilitation efforts.

Our results not only replicate but also extend previous results on the individual impact of hazardous drinking and TBI on mental health indicators.[19-20] Odd ratios among hazardous drinkers were significantly higher for elevated psychological distress, being prescribed medication for anxiety, depression or both, being prescribed medication for ADHD, suicidal ideation, suicide attempt, and self-rated fair or poor mental health. Adjusted odds ratios were higher among adolescents who reported former TBI for being prescribed medication for anxiety, depression or both, being prescribed medication for ADHD, suicidal ideation, suicide attempt, reporting fair or poor mental health, and calling a crisis line for help. Interestingly, self-rated fair or poor general health was not associated with TBI or hazardous drinking. Adolescents who reported recent TBI had adjusted odds 9 times higher of reporting attempted suicide in the past 12 months, than those who never had a TBI or were identified as hazardous drinkers. Suicide, is the third leading cause of death among people between the ages of 14 and 25, and has been linked with both TBI and hazardous drinking.[25,38-40] A recent systematic review of studies published between 2007-2012 revealed that the link between suicidal ideation and TBI was robust,[38] while a Canadian study of 235,000 adults found that adults with a history of concussions were three times more likely to die by suicide compared to individuals who never had a concussion.[39] Our results confirm that TBI (past and recent) and hazardous drinking are strongly related to suicidal ideation and suicide attempt in adolescents, and suggest that this link is intensified among adolescents experiencing both conditions.

This is the first population-based study to compare the individual impact of

current hazardous drinking and history of TBI with their combined effects on mental health and conduct behaviors outcomes. The results provide strong support for the suggestion that the negative effects of the co-occurrence of hazardous drinking with TBI may be synergistic. When hazardous drinking co-occurred with either *former or recent* TBI, the odds were significantly elevated for nearly all the mental health and perpetrator related violent and non-violent conduct behaviors, as well as reports of being the victim of being threatened with a weapon on school property or being bullied at school or via the internet, compared to reporting only TBI or hazardous drinking. The incremental impact of the co-occurrence of hazardous drinking and TBI has not previously been demonstrated, but it appears substantial.

At the same time, readers should be mindful of our study's limitations. First, the results are based on self-report and thus subject to bias that may affect validity. Second, the data are obtained from a cross-sectional survey and thus do not allow causal conclusions to be drawn. While our post-survey assessment of substance use and mental health indicators did not show evidence of appreciable bias, the survey's student response rate (63%), while considered normative for such studies, may be subject to nonresponse bias.[4] Although most clinical literature has investigated the relationship between TBI and mental health symptoms post TBI, alcohol misuse and mental health problems may also be linked to risk-taking behaviors that precipitate TBI. Finally, our operational definition of TBI excluded milder forms of the injury that leaves the individual confused or dazed without loss of consciousness, or with a loss of consciousness for less than 5 minutes.

Nevertheless, these results are of substantial interest. First, the results not only

replicate but extend findings that the joint occurrence of hazardous drinking and TBI among adolescents is associated with significant adverse mental health and conduct behavior correlates. The incremental negative consequences of the co-occurrence of hazardous drinking and TBI in an adolescent population we report is novel. Additionally, whether the TBI occurred in the past year or previously may be an important consideration. Separation of *recent* from *former TBI* strengthens the ability to make causal interpretations. The TBI-AUDIT classifications are temporally interpretable (e.g., past history of TBI versus current hazardous drinking assessment). This study contributes to the slowly developing international population studies assessing alcohol misuse and TBI.

Our results suggest that, when dealing with adolescents with a drinking problem, it may be important to look for history of TBI, and conversely, when dealing with adolescents with TBI, it may also be important to look for evidence of hazardous drinking, as co-occurrence appears to be associated with substantially greater mental health problems and conduct behaviours. Additional research to understand the incremental problems experienced by those with co-occurring hazardous drinking and TBI, and to understand the causal relationships involved, is greatly needed. Such examinations are crucial in helping guide clinicians, physicians, prevention and rehabilitation programs.

Author contributions: Drs. Ilie and Mann had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analyses.

Study concept and design: Ilie, Mann, Boak, Hamilton, Rehm, Cusimano

Acquisition of data: Mann, Hamilton, Boak

Analysis and interpretation of data: Ilie, Mann, Boak, Adlaf

Drafting of the manuscript: Ilie

Critical revision of the manuscript for important intellectual content: Ilie, Mann, Boak, Hamilton, Rehm, Cusimano

Statistical analysis: Ilie, Mann

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Data availability:

No additional data available**.**

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Table 1. Covariates and predictors included in the analysis

Variable	*Definition*
Sex – covariate	Male, female
Grade – covariate	Four categories: 9th, 10th, 11th, 12th
Mental health measures	
Psychological distress	Moderate to high vs. low psychological distress in the past 4 weeks GHQ[25]
Used prescribed medication to reduce anxiety, depression, or both	Past 12 months taking prescribed medication for anxiety, depression or both (yes=1, 0 otherwise)
Suicidal ideation	Seriously considered suicide in the past 12 months (yes= 1, 0 otherwise)
Suicide attempt	Attempted to commit suicide in the past 12 months (yes=1, 0 otherwise)
Called a crisis or help line in past 12 months	Called a youth crisis or help line in past 12 months for help (yes= 1; 0 otherwise)
Used prescribed medication to treat ADHD	Past 12 month use of prescribed medication to treat ADHD (yes=1, 0 otherwise)
Self-rated mental health status	Reported excellent/ good mental health vs. fair or poor mental health (yes=1; 0 otherwise)
Self-rated health status	Reporting excellent/ good health vs. fair or poor health in general (yes=1; 0 otherwise)
Violent and non-violent conduct behaviors (perpetrator or victim)	
Drove a car without the owner's permission	Taken the car for a ride without the owner's permission at least once in the past 12 month (yes=1; 0 otherwise)

Damage to property	Damaged something on purpose that did not belong to you at least one in past 12 months (yes=1; 0 otherwise)
Sold marijuana or hashish at school	Sold marijuana or hashish at least once in the past 12 months (yes=1; 0 otherwise)
Stealing (things worth 50$ or less)	Taken things worth $50 or less at least once in the past 12 months (yes=1; 0 otherwise)
Stealing (things worth more than 50$)	Taken things worth $50 or more at least once in the past 12 months (yes=1; 0 otherwise)
Physical violence (in purpose)	Beat up, hurt anyone in purpose at least once in the past 12 months (yes=1; 0 otherwise)
Physical violence at school	Engaged in a physical fight on school property at least once in past 12 months (yes=1; 0 otherwise)
Breaking into property	Times broken into a locked building other than one's own at least once in the past 12 months (yes=1; 0 otherwise)
Possession of a weapon (e.g., gun, knife) on school property	Carried a weapon such as a gun or a knife at least once in the past 12 months (yes=1; 0 otherwise)
Running from home	Ran away from home in the past 12 months (yes=1; 0 otherwise)
Set fire	Set something on fire you weren't supposed to at least once in the past 12 months (yes=1; 0 otherwise)
Bullied others	Bullied others at school at least once in the past 12 months (yes=1; 0 otherwise)
Being threatened with a gun or weapon at school (*Victim*)	Was threatened with a gun or a weapon on school property in the past 12 months (yes=1; 0 otherwise)
Being bullied at school (*Victim*)	Been bullied at school at least once in the past 12 months

	(yes=1; 0 otherwise)
Being bullied through the internet (*Victim*)	Been bullied through the internet once in the past 12 months (yes=1; 0 otherwise)

Table 2. Descriptive analyses predicting membership classification: TBI former (lifetime but not past 12 months; no current hazardous drinking); TBI recent (past 12 months; no current hazardous drinking), Hazardous Drinking (never had TBI), former TBI with co-occurring Hazardous Drinking (no recent TBI), recent TBI recent with co-occurring Hazardous Drinking, and base category (no TBI or Hazardous Drinking) by demographics, among adolescents grades 9 through 12, Ontario, Canada, 2013, n=3130

	Base category % (95% CI) OR (95% CI) n=2082	Former TBI (no Hazardous Drinking) % (95% CI) OR (95% CI) n=367	Recent TBI (no Hazardous Drinking) % (95% CI) OR (95% CI) n=104	Hazardous Drinking (no TBI) % (95% CI) OR (95% CI) n=390	Former TBI & Hazardous Drinking % (95% CI) OR (95% CI) n=117	Recent TBI & Hazardous Drinking % (95% CI) OR (95% CI) n=70
Sex	F (5, 94) = 1.08					
Male	62.0 (57.4,66.5) 1.00 (Ref) n=864	12.6 (10.0,15.8) 1.23 (.85,1.78) n=187	4.4 (3.0,6.6) 1.31 (.67, 2.53) n=51	13.5 (11.6,15.7) 1.03 (.78,1.37) n=155	5.1 (3.1,8.4) 1.79 (.93,3.44) n=60	2.3 (1.4,3.8) 1.16 (.57,2.32) n=34
Female (Ref.)	66.3 (62.5,69.8) n=1218	11.0 (8.8,13.6) n=180	3.6 (2.2,6.0) n=53	13.9 (11.7, 16.6) n=235	3.1 (2.1, 4.4) n=57	2.1 (1.4, 3.1) n=36
Grade	F (15, 84)=14.37***					
12	72.1 (68.6,75.3) 1.00 (Ref.) n=458	14.8 (11.8,18.4) .84 (.52, 1.34) n=60	6.5 (4.4,9.5) .84 (.39, 1.79) n=22	4.8 (3.2,7.1) 6.35(4.16,9.69)*** n=162	0.8 (0.3,1.9) 11.75(4.03,34.27)*** n=46	1.1 (0.5,2.5) 3.07(1.16,8.15)** n=24
11	71.1 (65.9,75.7) 1.00 (Ref.) n=518	13.3 (10.0,17.4) .85 (.55, 1.30) n=88	2.4 (1.2,4.8) .58 (.32, 1.04) n=22	8.0 (4.9,12.8) 3.58(1.98,6.46)*** n=125	2.5 (1.3, 4.9) 7.88(2.96,20.95)*** n=35	2.8 (1.4,5.5) 2.47(.74,8.24) n=21
10	63.2 (57.4,68.6) 1.00 (Ref.) n=548	11.0 (8.2,14.5) .91 (.65, 1.28) n=110	3.3 (1.9,5.7) .37 (.18, .78) n=24	15 (11.1,19.9) 1.69 (.87,3.39) n=63	5.3 (3.7,7.4) 3.37(1.06,10.76)* n=22	2.4 (1.0,5.6) 2.57(.84,7.89) n=14
9 (Ref.)	54.4 (48.9,59.7) n=558	9.4 (6.9,12.6) n=109	4.1 (2.2,7.6) n=36	22.9 (19.6,26.5) n=40	6.7 (4.2,10.7) n=14	2.5 (1.6,3.8) n=11

Table 3. Multinomial Logistic Regression analyses predicting membership classifications: TBI former (lifetime but not past 12 months; no current hazardous drinking); TBI recent (past 12 months; no current hazardous drinking), Hazardous Drinking (never had TBI), former TBI with co-occurring Hazardous Drinking (no recent TBI), recent TBI recent with co-occurring Hazardous Drinking, and base category (no TBI or Hazardous Drinking) by mental health measures among adolescents grades 9 through 12, Ontario, Canada, 2013, n=3130

	Former TBI (no Hazardous Drinking) n=367 vs. Base Category (Ref.) n=2082 OR (95% CI) AOR (95% CI)	Recent TBI (no Hazardous Drinking) n=104 vs. Base Category (Ref) n=2082 OR (95% CI) AOR (95% CI)	Hazardous Drinking (no TBI) n=390 vs. Base Category (Ref.) n=2082 OR (95% CI) AOR (95% CI)	Former TBI & Hazardous Drinking n=117 vs. Base Category (Ref.) n=2082 OR (95% CI) AOR (95% CI)	Recent TBI & Hazardous Drinking n=70 vs. Base Category (Ref.) n=2082 OR (95% CI) AOR (95% CI)
Moderate to high levels vs. low levels of psychological distress					
$F(5,94) = 7.29^{***}$	1.17 (.80, 1.73)	1.15 (.54, 2.43)	1.49 (1.17, 1.90)**	3.10 (1.67, 5.75)***	2.14 (1.07, 4.30)*
$F(15,84) = 9.80^{***}$	1.25 (.87, 1.81)	1.24 (.64, 2.40)	1.65 (1.29, 2.13)***	4.06 (2.21, 7.44)***	2.36 (1.11, 5.02)*
Past 12 months prescription medication for anxiety, depression or both					
$F(5,94) = 6.36^{***}$	2.26(1.08,4.73)*	1.90 (.65, 5.55)	2.11 (1.13, 3.96)*	6.15 (2.75, 13.77)***	6.24 (2.73, 14.28)***
$F(15,84) = 11.80^{***}$	2.44 (1.18, .07)*	2.08 (.73, 5.86)	1.74 (.81, 3.73)	6.02 (2.59, 13.0)***	6.17 (2.64, 14.42)***
Past 12 months did you contemplate attempt suicide					

F (5,90) = 7.49*** F (15,80) = 11.80***	1.65 (1.12,2.45)* 1.74(1.17,2.57)**	1.98 (.88, 4.49) 2.11 (.99, 4.47)	1.88 (1.31, 2.70)** 2.17 (1.50, 3.13)***	2.71 (1.29, 5.69)** 3.48 (1.62, 7.48)**	4.45 (1.90, 10.42)** 4.96 (2.07, 11.90) ***
Past 12 months did you actually attempt suicide					
F (5,90) = 15.93*** F (15,80) =14.29***	4.43(2.27,8.64)*** 4.81(2.48,9.35)***	8.14(2.68,24.73)*** 9.14(3.22,25.93)***	5.03 (2.64, 9.58)*** 6.45 (3.09, 13.48)***	6.36 (2.11, 19.14)** 9.70 (3.37, 27.96)***	24.77(9.10, 67.42)*** 31.23(10.29,94.82)***
Called a child crisis or help line in past 12 months					
F (5, 94) = 5.34*** F (15, 84)=9.77***	2.05(1.49, 6.26)** 3.26(1.58, 6.74)**	.32 (.08, 1.23) .34 (.09, 1.34)	2.12 (1.01, 4.43)* 2.11 (.99, 4.46)	3.20 (1.05, 9.70)* 3.75 (1.24, 11.33)*	5.49 (2.0, 15.08)** 5.80 (2.13, 15.80)**
Past 12 months used prescribed medication to treat ADHD					
F (5, 94) = 4.10** F(15,84)=11.32***	2.99 (1.32,6.79)** 2.88 (1.25, 6.59)*	5.39 (.97, 30.05) 5.12 (.93, 28.14)	2.86 (1.45, 5.62)** 2.99 (1.47, 6.06)**	5.23 (1.90, 14.37)** 5.00 (1.74, 14.41)**	7.29 (1.83, 29.01)** 7.33 (1.90, 28.30)**
Reporting fair or poor mental health in general vs. excellent/ good mental health					
F (5, 94) = 5.18*** F (15, 84) =8.79***	1.53 (1.03, 2.28)* 1.61 (1.10, 2.36)*	1.30 (.58, 2.87) 1.38 (.68, 2.80)	1.31 (.98, 1.77) 1.40 (1.02, 1.91)*	3.37 (1.71, 6.64)** 3.93 (2.03, 7.61)***	2.85 (1.42, 5.74)** 3.07 (1.46, 6.44)**
Reporting fair or poor health in general vs. excellent/ good health					
F(5, 94) = .20 F(15, 84)=10.83***	.98 (.59, 1.64) .99 (.59, 1.66)	1.10 (.38, 3.17) 1.11 (.39, 3.18)	1.15 (.63, 2.10) 1.12 (.62, 2.04)	1.40 (.61, 3.20) 1.40 (.63, 3.12)	1.25 (.33, 4.65) 1.23 (.34, 4.48)

Notes: F - design adjusted Wald F tests; Odds Ratios (OR) and Adjusted Odds Ratios (AOR) were calculated using logistic

regression. AORs were evaluated while holding fixed values of the complexity of the design, sex and grade; *** P < 0.001; ** P < 0.01; * P<0.05

Table 4. Multinomial Logistic Regression analyses predicting group membership classifications: TBI former (lifetime but not past 12 months; no current hazardous drinking); TBI recent (past 12 months; no current hazardous drinking), Hazardous Drinking (never had TBI), former TBI with co-occurring Hazardous Drinking (no recent TBI), recent TBI recent with co-occurring Hazardous Drinking, and base category (no TBI or Hazardous Drinking) by conduct behaviours among adolescents grades 9 through 12, Ontario, Canada, 2013, n=3130.

	Former TBI (no Hazardous Drinking) n=367 vs. Base Category (Ref.) n=2082 OR (95% CI) AOR (95% CI)	Recent TBI (no Hazardous Drinking) n=104 vs. Base Category (Ref) n=2082 OR (95% CI) AOR (95% CI)	Hazardous Drinking (no TBI) n=390 vs. Base Category (Ref.) n=2082 OR (95% CI) AOR (95% CI)	Former TBI & Hazardous Drinking n=117 vs. Base Category (Ref.) n=2082 OR (95% CI) AOR (95% CI)	Recent TBI & Hazardous Drinking n=70 vs. Base Category (Ref.) n=2082 OR (95% CI) AOR (95% CI)
Taken the car for a ride without the owner's permission					
F (5,94)=26.32***	2.14 (.95, 4.82)	4.29 (1.35, 13.65)*	6.48(4.02,10.43)***	17.92 (9.57, 33.55)***	3.17 (.97,10.39)
F (15,84)=14.52***	2.17 (.97, 4.88)	4.27 (1.33, 13.69)*	5.61 (3.53, 8.94)***	15.15 (7.77, 29.56)***	2.93 (.87, 9.93)
Damaged something on purpose					
F (5,94)=14.57***	1.46 (.89, 2.38)	6.21(2.76,13.98)***	2.72 (1.65, 4.49)***	5.50 (2.50, 12.07)***	9.29(4.44,19.44)***
F (15,84)=21.56***	1.42 (.87, 2.33)	6.13 (2.67, 14.06)***	3.14 (1.86, 5.29)***	6.16 (2.65, 14.31)***	9.98 (4.65, 21.44)***
Sold marijuana or hashish					
F (5.94)=31.48***	2.51 (1.26, 5.02)*	10.16 (3.22,32.06)***	12.11 (6.86,21.36)***	29.29 (16.63,51.58)***	8.82 (3.25, 23.97)***
F(15,84)=18.00***	2.41 (1.74, 4.95)*	9.80(3.21,29.94)***	13.35 (6.37,27.98)***	29.71 (14.88,59.31)***	9.02 (2.86, 28.45)***
Taken things worth $50 or less					
F (5,94)=19.02***	2.07 (1.31, 3.25)**	2.18 (1.06, 4.45)*	5.17 (3.18, 8.39)***	6.92 (4.02, 11.91)***	2.59 (.78, 8.54)

F (5,84)=20.06***	2.04 (1.30, 3.22)**	2.12 (1.02, 4.12)*	5.31 (3.43, 8.22)***	6.69 (3.86, 11.59)***	2.57 (.78, 8.49)
Stealing more than $50					
F (5,94)=11.28***	1.62 (.59, 4.47)	2.83 (.86, 9.33)	7.77 (3.39, 17.82)***	15.17 (5.93, 38.84)***	8.13 (2.41, 27/36)**
F (15,84)=13.97***	1.62 (.58, 4.54)	2.75 (.83, 9.12)	7.05 (2.96, 16.81)***	12.88 (4.70, 35.30)***	7.61 (2.24, 25.87)**
Beat up, hurt anyone in purpose					
F (5,94)=18.08***	2.40 (1.22, 4.75)*	4.34 (1.84, 10.20)**	4.97 (2.71, 9.10)***	9.61 (4.93, 18.73)***	8.64 (2.98, 25.04)***
F (15,84)=17.64***	2.31 (1.15, 4.64)*	4.18 (1.77, 9.84)**	5.98 (3.16, 11.32)***	11.06 (5.26, 23.24)***	9.40 (3.19,27.66)***
Broken into a locked building other than one's own					
F (5,94)=20.49***	.48 (.18, 1.30)	1.92 (.59, 6.26)	4.81 (2.31, 10.05)***	8.70 (3.83, 19.78)***	9.43 (2.84, 31.34)***
F (15,84)=10.72***	.48 (.18, 1.26)	1.85 (2.08, 6.46)	4.79 (2.08, 11.05)***	8.01 (3.12, 20.62)***	9.26 (2.59, 33.13)***
Carried a weapon such as a gun or a knife					
F (5,94)=13.767***	5.13 (2.81,9.35)***	6.66 (2.75, 16.10)***	5.67 (2.82, 11.38)***	9.99 (4.85, 20.57)***	9.21 (3.57, 23.74)***
F (15,84)=29.00***	4.92 (2.69,8.97)***	6.40 (2.35, 17.43)***	7.67 (3.95, 14.90)***	12.73 (5.79, 27.99)***	10.71(4.06,28.20)***
Run away from home					
F (5,94)=13.67***	1.76 (.99, 3.13)	3.67 (2.30, 5.84)***	4.16 (2.56, 6.77)***	4.85 (2.01, 11.73)**	4.49 (1.57, 12.86)**
F (15,84)=12.60***	1.78 (.99, 3.16)	3.78 (2.44, 5.86)***	4.55 (2.82, 7.33)***	5.79 (2.16, 15.52)**	4.74 (1.59, 14.17)**
Set fire					
F (5,94)=14.58***	1.47 (.94, 2.29)	3.04 (1.26, 7.35)*	4.00 (2.69, 5.92)***	6.07 (3.03, 12.16)***	3.54 (1.36, 9.20)*
F (15,84)=24.63***	1.40 (.92, 2.14)	2.96 (1.17, 7.46)*	5.34 (3.41, 8.37)***	7.88 (3.77, 16.47)***	4.02 (1.59, 10.15)**
In a physical fight on school property					
F (5,94)=6.65***	2.36 (1.42, 3.92)**	6.59 (2.77, 15.68)***	1.98 (.96, 4.11)	4.91 (2.26, 10.68)***	4.21 (1.55, 11.46)**
F (15,84)=15.92***	2.25 (1.38, 3.66)**	6.78 (2.70, 17.01)***	2.50 (1.14, 5.49)*	5.62 (2.28, 13.83)***	4.77 (1.77, 12.86)**
Bullied others at school					
F (5,94)=10.05***	1.52 (1.00, 2.32)	1.56 (.54, 4.50)	2.12 (1.40, 3.20)***	4.54 (2.62, 7.85)***	3.81 (1.85, 7.83)***

F (5,84)=14.74***	1.48 (.98, 2.25)	1.52 (.52, 4.49)	2.50 (1.61, 3.89)***	5.24 (2.93, 9.37)***	4.11 (2.05, 8.26)***
Was threatened with a gun or a weapon (VICTIM)					
F (5,94)=9.20***	2.72 (1.42, 5.24)**	7.35 (2.39, 22.60)**	2.48 (1.27, 5.29)*	7.19 (2.18, 16.25)***	6.72 (2.64, 17.16)***
F (5,84)=17.53***	2.61 (1.37, 4.95)**	7.12 (2.35, 21.55)**	2.90 (1.29, 6.52)*	7.97 (3.25, 19.55)***	7.20 (2.87, 18.08)***
Been bullied at school (VICTIM)					
F (5,94)=3.33**	1.63 (1.15, 2.31)*	2.04 (1.06, 3.95)*	1.24 (.88, 1.74)	2.07 (1.00, 4.30)	2.44 (1.20, 4.95)*
F (5,84)=9.41***	1.63 (1.16, 2.28)*	2.08 (1.12, 3.87)*	1.52 (1.08, 2.15)*	2.77 (1.34, 5.71)**	2.77 (1.37, 5.57)**
Been bullied through the internet (VICTIM)					2.64 (1.22, 5.70)*
F (5,94)=6.73***	1.55 (1.03, 2.34)*	3.22 (1.47, 7.10)**	1.48 (.99, 2.22)	3.29 (1.80, 6.02)***	2.94 (1.20, 6.64)*
F (5,84)=12.34***	1.56 (1.03, 2.38)*	3.36 (1.48, 7.64)**	1.76 (1.18, 2.64)**	4.17 (2.18, 7.98)***	

Notes: F - design adjusted Wald F tests; Odds Ratios (OR) and Adjusted Odds Ratios (AOR) were calculated using logistic regression.

aORs were evaluated while holding fixed values of the complexity of the design, sex and grade; *** P < 0.001; ** P < 0.01; * P<0.05

Table 5. Multinomial Logistic Regression analyses predicting membership classifications by history of TBI and Hazardous Drinking: either History of TBI or Hazardous Drinking, separately; no History of TBI or Hazardous Drinking; co-occurring History of TBI with current Hazardous Drinking for mental health and conduct behaviors measures, n=3130

	No history of TBI or hazardous drinking (n=2082) vs. History of TBI or Hazardous Drinking (n=881) OR (95% CI) AOR (95% CI)	History of TBI with hazardous drinking (n=187) vs. History of TBI or Hazardous Drinking (n=881) OR (95% CI) AOR (95% CI)
Mental health measures		
Moderate to high levels vs. low levels of psychological distress F (2,352) = 24.11*** F (2,355) = 24.27***	.68 (.55, .85)*** .66 (.53, .82)***	2.26 (1.51,3.39)*** 2.42 (1.16, 3.63)***
Past 12 months prescription medication for anxiety, depression or both F (2,181) = 6.36*** F (2,180) = 12.60***	.46 (.26,.84)*** .49 (.26, .92)***	2.89 (1.63,5.12)*** 2.98 (1.68, 5.29)***
Past 12 months did you contemplate attempt suicide F (2,339) = 17.82*** F (2,333) = 19.99***	.57 (.44,.75)*** .53 (.40,.70)***	1.95 (1.19,3.17)* 2.17 (1.21,3.58)***
Past 12 months did you actually attempt suicide F (2,327) = 25.34*** F (2,306) = 28.17***	.26 (.17,.41)*** .23 (.15,.35)***	2.39 (1.21,4.72)*** 2.95 (1.39,6.26)***
Called a child crisis or help line in past 12 months F (2,355) = 10.98*** F (2,349) = 12.32***	.34 (.28,.68)*** .40 (.26, .62)***	1.65 (.82,3.32) 1.81 (.86,3.79)
Past 12 months used prescribed medication to treat ADHD		

F (2,346) = 12.11***	.32 (.18, .58)***	2.01 (.85, 4.72)
F (2,346) = 10.54***	.32 (.18,.57)***	2.04 (.82,5.05)
Reporting fair or poor mental health in general vs. excellent/ good mental health		
F (2,318) = 21.10***	.63 (.51,.68)***	2.33 (1.42, 3.84)***
F (2,312) = 22.03***	.61 (.50, .75)***	2.44 (1.48,4.03)***
Reporting fair or poor health in general vs. excellent/ good health		
F(2,302) = .91	.80 (.51,1.24)	1.15 (.55,2.38)
F (2,336) = .81	.80 (.50,1.28)	1.16 (.57, 2.34)
Conduct behaviours		
Taken the car for a ride without the owner's permission		
F (2,320)=46.22***	.21 (.13,.34)***	3.04 (1.95,4.76)***
F (2,329)=31.17***	.26 (.16,.41)***	2.49 (1.54,4.03)***
Damaged something on purpose		
F (2,352)=33.68***	.42 (.30,.59)***	2.85 (1.75,4.65)***
F (2,348)=32.07***	.41 (.29,.58)***	3.00 (1.78,5.08)***
Sold marijuana or hashish		
F (2,329)=43.92***	.14 (.08,.26)*	3.11 (1.78,5.46)***
F(2,340)=34.01***	.17 (.09,.30)*	2.76 (1.52,5.00)***
Taken things worth $50 or less		
F (2,355)=48.78***	.29 (.22,.39)***	1.76 (1.12,2.76)***
F (2,350)=41.12***	.32 (.24,.42)***	1.59 (.99,2.54)
Stealing more than $50		
F (2,356)=24.93***	.22 (.12,.42)***	3.20 (1.59,6.44)***
F (2,356)=18.19***	.26 (.14,.49)***	2.71 (1.31,5.62)***
Beat up, hurt anyone in purpose		
F (2.253)=35.61***	.29 (.19,.433)***	2.54 (1.46,4.41)***
F (2,253)=33.70***	.28 (.18,.42)***	2.76 (1.54,4.95)***
Broken into a locked building other than one's own		
F (2,355)=25.58***	.33 (.17,.64)***	4.41 (2.19,8.89)***
F (2,355)=15.39***	.38 (.19,.75)***	1.85 (1.18,2.53)***
Carried a weapon such as a gun or a knife		
F (2,326)=32.61***	.21 (.12,.35)***	2.08 (1.16,3.74)***

F (2,334)=33.92***	.20 (.12,.33)***	2.34 (1.23,4.44)***
Run away from home		
F (2,326)=22.81***	.33 (.24,.46)***	1.72 (.89,3.34)
F (2,307)=18,15***	.33 (.24,.47)***	1.75 (.84,3.66)
Set fire		
F (2,340)=22.86***	.43 (.30,.62)***	1.95 (1.22,3.10)***
F (2,345)=27.65***	.41 (.29,.58)***	2.17 (1.35,3.49)***
In a physical fight on school property		
F (2,349)=18.53***	.46 (.32,.65)***	1.77 (1.07,2.94)*
F (2,343)=25.03***	.39 (.28, .54)***	2.11 (1.21,3.71)**
Bullied others at school		
F (2,354)=23.23**	.64 (.50,.82)***	2.55 (1.63,3.97)***
F (2,354)=26.61***	.61 (.48,.79)***	2.79 (1.77,4.39)***
Was threatened with a gun or a weapon (VICTIM)		
F (2,329)=16.37***	.39 (.25, .61)***	2.25 (1.06,4.77)*
F (2,325)=18.27***	.37 (.24,.57)***	2.45 (1.12,5.36)**
Been bullied at school (VICTIM)		
F (2,346)=7.97***	.67 (.54,.84)***	1.31 (.79,2.18)
F (2,344)=16.93***	.57 (.45,.71)***	1.65 (1.01,2.73)
Been bullied through the internet (VICTIM)		
F (2,354)=23.23**	.60 (.46,.78)***	1.71 (1.02,2.88)*
F (2,347)=18.66***	.53 (.41,.69)***	1.99 (1.16,3.43)***

Notes: F - design adjusted Wald F tests; Odds Ratios (OR) and Adjusted Odds Ratios (AOR) were calculated using logistic regression. AORs were evaluated while holding fixed values of the complexity of the design, sex and grade; *** P < 0.001; ** P < 0.01; * P<0.05

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

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Provided-p2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Provided-p2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported Provided-p.5-6
Objectives	3	State specific objectives, including any pre-specified hypotheses Provided-p6
Methods		
Study design	4	Present key elements of study design early in the paper Presented-p.6-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection Provided in methods-p6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants Provided in methods-p6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable Provided in methods-p.7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group Provided in methodsp.8-9
Bias	9	Describe any efforts to address potential sources of bias Provided in discussion=p.16
Study size	10	Explain how the study size was arrived at Provided in methods-p.9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why Provided-p.7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding √-p9
		(*b*) Describe any methods used to examine subgroups and interactions √-p.12
		(*c*) Explain how missing data were addressed √p.9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy √p.8-9
		(*e*) Describe any sensitivity analyses - n/a
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed – Provided-p.9, also Tables 1-5 provide ns.,

		p.25-
		(b) Give reasons for non-participation at each stage – n/a
		(c) Consider use of a flow diagram – n/a
Descriptive data	14*	(a) Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders – Provided plus online link to supplementary methods of the sample-p.6-7
		(b) Indicate number of participants with missing data for each variable of interest – p.9, plus on-line link in methods p.7
Outcome data	15*	Report numbers of outcome events or summary measures – Provided-Table 1-p.25
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included – Provided- Tables 1-5, p25-37
		(*b*) Report category boundaries when continuous variables were categorized – n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – n/a
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses – n/a
Discussion		
Key results	18	Summarise key results with reference to study objectives – Provided- p.3, p.13-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias – Provided-p.16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – Provided-p.16
Generalisability	21	Discuss the generalisability (external validity) of the study results – Provided-p.16-17
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based – Provided-p.18

*Give information separately for exposed and unexposed groups.

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A cross-sectional examination of the association of co-occurring alcohol misuse and traumatic brain injury on mental health and conduct problems in adolescents in Ontario, Canada.

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Running head: Comorbid health correlates of TBI and hazardous drinking among adolescents

A cross-sectional examination of the association of co-occurring alcohol misuse and traumatic brain injury on mental health and conduct problems in adolescents in Ontario, Canada.

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ABSTRACT

Objective: This study describes the impact of traumatic brain injury (TBI) and hazardous drinking on mental health and behavioral issues among Ontario adolescents. In particular, we assessed the incremental co-occurrence of hazardous drinking with history of TBI, in comparison to experiencing just one of these conditions.

Method: A cross-sectional subsample of 3130 Ontario adolescents attending grades 9 through 12, ages 10 through 21 were surveyed in 2013 as part of the Centre for Addiction and Mental Health's Ontario Student Drug Use and Health Survey. *Recent* (past year) and *former* (lifetime, excluding last year) TBI were defined as trauma to the head that resulted in loss of consciousness for at least five minutes or overnight hospitalization. Current hazardous drinking was derived using the Alcohol Use Disorders Identification Test (AUDIT).

Results: An estimated 11.8% (95% CI: 10.1, 13.8) reported a history of *former* TBI and were not hazardous drinkers; 4.0% (95% CI: 2.9, 5.5) reported *recent* TBI and were not hazardous drinkers; 13.7% (95% CI: 12.3, 15.3) were hazardous drinkers who never had a TBI; 4.1% (95% CI: 2.9, 5.8) had *former* TBI with co-occurring hazardous drinking; and 2.2% (95% CI: 1.6, 3.0) had *recent* TBI with co-occurring hazardous drinking. Most odds increased significantly and were between 2 to 3 times higher for reporting compromised mental health, violent and non violent conduct behaviors, and reported victimization for classifying as hazardous drinker at the time of testing with co-occurring either *former* or *recent* TBI compared to classifying as not having either of these conditions. Adolescents classified as hazardous drinkers with *former* TBI had

numerous and higher odd ratios for conduct behaviors than hazardous drinkers with *recent* TBI.

Conclusion: Results emphasize the strong interplay between TBI and hazardous drinking, and point to the need for integrating prevention efforts to reduce these conditions and their co-occurrence among adolescents.

ARTICLE SUMMARY

Strengths and limitations of this study:

- The study shows that the emergence of hazardous drinking over the high school years may occur at an elevated rate among adolescents with traumatic brain injury (TBI).
- This is the first time when temporarily interpretable patterns of association between hazardous drinking and history of TBI among adolescents were examined in the context of co-occurring mental health and problem behaviours in a population based study.
- Adolescents who classified as hazardous drinkers at the time of testing, with *former* lifetime history of TBI (that occurred prior to past 12 months), had numerous and higher odd ratios for conduct behaviors than hazardous drinkers with r*ecent* TBI (that occurred in the past 12 months).
- Hazardous drinkers with *recent TBI* had more and higher odd ratios for most mental health behaviors than hazardous drinkers with *former TBI*.
- These results demonstrate that whether the TBI occurred recently (past year) or previously (prior to last year) may be an important consideration for

management for these conditions and rehabilitation efforts.

- Possible bias related to self-report procedures and the preclusion of causal inferences due to the cross-sectional nature of the data are limitations of this study.
- Even though our data did not present evidence of appreciable bias overall, nonresponse bias may exist.

KEYWORDS: Traumatic brain injury, hazardous drinking, mental health, violence, adolescents

Introduction

Excessive drinking in adolescence can cause substantial harm to individuals, and is associated with future alcohol-related problems.[1-3] Drinking in adolescence is particularly risky because it is much more likely to be heavy and episodic (binge).[4-5] Excessive drinking during adolescence, while the brain is still developing, can be a major cause of trauma, physical injuries, hospitalization, prolonged disability and premature death.[1-3,6] Alcohol contributes substantially to motor vehicle collisions, homicides, suicide, assault, sexual risk-taking, and many other problems in Canada and the US.[7-16]

Hazardous drinking is both a contributor to and a consequence of traumatic brain injury (TBI).[17-18] Traumatic brain injuries (TBI) occur when a sudden trauma (hit or blow to the head) causes damage to the brain. An estimated one in 5 adolescents in Ontario has experienced TBI in their lifetime, and one in 18 has experienced it during the past 12 months.[19-20] Hospitalization data revealed that almost half of the individuals presenting with brain injuries were intoxicated upon hospital admission, and among adolescents and adults who required inpatient rehabilitation post TBI, over 60% were found to have had a history of alcohol or other drug misuse.[21-23] Adolescents who had experienced one or more TBIs in their lifetime had odds twice as much, to screen positive for current hazardous drinking or for reporting binge drinking in the past 12 months, compared to those who never had a TBI.[20]

Both TBI and hazardous drinking are relatively common among adolescents[4,19,20] and both have been linked with poor academic performance, mental health issues including suicide, and increased violent and non-violent conduct

behaviors.[19,24-29] Several studies using imaging methods have noted negative additive effects of alcohol misuse and TBI, such as brain atrophy over time and reduced reaction times.[30-32]

However, no studies have compared the separate and joint effects of hazardous drinking and TBI in general population or clinical samples of adolescents. Specifically, although previous research shows that both hazardous drinking and a history of TBI are associated with harmful health outcomes, that include mental health and behavioral issues, the incremental impact of having both of these conditions is unknown.[4,19-20,25-32] This study examines the association of history of TBI and hazardous drinking, separately and jointly, with past year mental health and conduct behaviors in a large representative sample of high school adolescents, in Ontario.

Methods

Data were based on a subsample of 3264 students in grades 9 to 12 and were derived from the 2013th cycle of the Centre for Addition and Mental Health's (CAMH) Ontario Student Drug Use and Health Survey (OSDUHS), a biennially repeated cross-sectional probability survey of Ontario students enrolled in four provincially-funded jurisdictions (Public vs. Catholic; English vs. French). In 2013, students were recruited from 198 schools and 671 classes dispersed province wide. Schools excluded from sampling were private, military, and institutional schools. With these exclusions our sample captures 92% of all Ontario children and adolescents aged 12 to 18.

Students completed self-administered, anonymous pen-and-paper questionnaires in their classrooms between November 2012 and June 2013. Participation rates were 61% for schools, 87% for classes, and 63% for students. A comparison between high (≥

70%) and low responding classes showed no evidence of nonresponse bias for a number of health-relate behaviours including TBI and the AUDIT.[4] Students completed one of two questionnaires (Form A or Form B) alternately distributed (i.e., A, B, A) within each class. Although the TBI items were asked of all students using forms A and B, because the AUDIT screener was contained in form A only, the estimation samples were reduced from 6159 to 3264 students. Detailed description of the sampling design and survey procedures is web-available.[4,33] The study was approved by the Research Ethics Committees of the Centre for Addiction and Mental Health (CAMH), St. Michael's Hospital (SMH), participating Ontario Public and Catholic school boards, and York University, which administered the surveys. All participants provided their assent in addition to parentally signed consent for those aged under 18.

Measures

Group membership categorization.

Our key analytical measure was derived from hazardous drinking and history of TBI. Hazardous or harmful drinking was derived using the 10-item AUDIT screener, a well-validated instrument assessing drinking frequency, volume, heavy consumption and indicators of abuse and dependence due to alcohol.[34] A cut score at or above 8 of 40 indicates a pattern of hazardous or harmful drinking.[35]

Traumatic brain injury (TBI) was based on two questions that asked students if they ever had a blow or a hit to the head that rendered them unconscious for at least five minutes or resulted in their hospitalization for at least one night. This criteria is also employed in diagnostic classification systems including DSM-IV and has previously been used in adolescent and adult studies.[36] Students were then asked if they ever had

such injury in the 12 months prior (recent TBI) or in their lifetime, but not in the 12 months prior (former TBI). Our analytic variable was formed by cross-tabulating these two measures to create out a 6-class membership variable.

Mental health problems, conduct behaviors and covariates are summarized in Table 1. The first set of analyses (Tables 2 through 4) were based on the following 6 levels classifications. The baseline classification included adolescents who never had a TBI and screened negative for hazardous drinking on the AUDIT at the time of testing. The second classification included adolescents with *former TBI* (experienced sometimes during their lifetime but not in past 12 months) and were not hazardous drinkers. Members in the third classification included adolescents with *recent TBI* (experienced in the past 12 months) and were not hazardous drinker. The fourth classification included adolescents who screened positive on the AUDIT at the time of testing (hazardous drinkers) but did not report TBI (*no former or recent*). The fifth classification included current hazardous drinkers with co-occurring *former TBI*, and the six classification included hazardous drinkers with co-occurring *recent TBI* (no *former TBI*). The second set of analyses (Table 5) were based on the following 3 levels classifications: adolescents who did not report a TBI (former or recent) nor did they screen positive on the AUDIT; adolescents who reported either former or recent TBI, or who screened positive on the AUDIT; and adolescents who screened positive on the AUDIT and also reported either former or recent TBI.

Analysis

Data derived from complex surveys using stratification and clustering fail the assumption of independent observations and thus underestimate variances (and in doing

they overstate significance levels resulting in false positive inferences). We therefore employed design-based estimation methods to accommodate such violations. Our subsample analyses utilized a complex sample design with 20 strata (region by school level), and 198 primary sampling units (high schools). The variance of our analyses was estimated by Taylor Series Linearization (TSL) executed in the Complex Sample module in SPSS version 23.0 (SPSS Inc., 2015). In addition to strata and clusters, our analyses employed case weights that factored inclusion probabilities, nonresponse and post stratification adjustments. We applied multinomial logistic regressions to assess the association between TBI-AUDIT classes with the 8 mental health, and 15 conduct behaviors, with and without holding sex and grade constant, against $P < 0.05$ (two-tailed). The results are based on 'valid' responses (n's); missing data (i.e. 'don't know' responses and refusals) were excluded. Listwise deletion reduced the estimation sample from 3264 to 3130.

Results

An estimated 11.8% (95% CI: 10.1, 13.8) of Ontario adolescents reported *former TBI*, 4.0% (95% CI: 2.9, 5.5) reported recent TBI, 13.7% (95% CI: 12.3, 15.3) were identified as hazardous drinkers, 4.1% (95% CI: 2.9, 5.8) reported *former TBI* with co-occurring hazardous drinking, 2.2% (95% CI: 1.6, 3.0) reported *recent TBI* with co-occurring hazardous drinking, and 64.1% (95% CI: 60.9, 67.2) were individuals who never had a TBI and scored negative on the AUDIT.

Demographic characteristics

Table 2 presents the demographic characteristics of the sample by TBI-AUDIT classifications. Odds ratios were similar for males versus females on all 6 TBI-AUDIT

classifications, while grade level in high-school significantly predicted TBI-AUDIT classification. Among adolescents in grade 12, odds ratios were 6 times significantly higher for hazardous drinking, nearly 12 times higher for reporting *former TBI* with co-occurring hazardous drinking, and 3 times higher for reporting *recent TBI* with co-occurring hazardous drinking, compared to baseline classification (neither conditions). Adolescents in grade 11 had odds nearly 4 times higher for hazardous drinking, and nearly 8 times higher for reporting *former TBI* with co-occurring hazardous drinking, compared to baseline classification. Among students in grade 10 the odds were 3 times higher for reporting *former TBI* with co-occurring hazardous drinking, compared to baseline classification.

Associations between TBI, problem drinking and recent Mental Health problems

Table 3 shows the results of multinomial regression analyses fitting TBI-AUDIT classification by mental health conditions. For 5 of the 8 mental health conditions, adjusted odds ratios associated with screening positive for hazardous drinking, without co-occurring history of TBI, were statistically significant, compared to individuals in the baseline classification (neither conditions) and ranged from 1.40 to 6.45. For 6 of the 8 mental health conditions assessed, adjusted odds ratios associated with *former TBI*, without co-occurring hazardous drinking, were statistically significant and ranged from 1.61 to 4.81. Only one of the 8 mental health conditions assessed had significant adjusted odds ratios associated with *recent TBI*. Adjusted odds were 9.14 times higher for suicide attempt among adolescents with *recent TBI* compared to those with no history of TBI that screened negative for hazardous drinking.

With the addition of hazardous drinking to *former TBI*, the adjusted odds ratios associated with 7 of 8 mental health conditions assessed increased, compared to either classification alone, and were statistically significant ranging from 3.75 to 9.70. With the addition of hazardous drinking to *recent TBI*, the adjusted odds-ratios associated with 7 of the 8 mental health conditions assessed increased, compared to either classification alone, and were statistically significant, ranging from 2.36 to 31.23. Self rated general health was not statistically significantly associated with any of the TBI-AUDIT classifications.

Associations between TBI, problem drinking and recent conduct behavioral issues

Table 4 shows the results of multinomial regression predicting membership in the 6 TBI-AUDIT classifications by 15 conduct behaviors. For 5 of 12 perpetrator behaviors, statistically significant adjusted odds ratios were associated with *former TBI* compared to the baseline classification (neither conditions). With the addition of hazardous drinking to *former TBI*, the adjusted odds-ratios associated with perpetrator reports of conduct behavior were higher and statistically significant on all 12 measures and ranged between 5.24 and 29.71. For all of the conduct behaviors in which the adolescent reported being a victim, adjusted odds ratios associated with *former TBI*, without hazardous drinking, were statistically significant and ranged between 1.56 and 2.61. With the addition of hazardous drinking to *former TBI*, compared to the baseline classification, the adjusted odds-ratios associated with all 3 conduct behavior victimization variables were statistically significant and ranged between 3.17 and 7.97.

For 9 of the 12 perpetrator type conduct behaviors assessed, statistically significant adjusted odds ratios associated with *recent TBI* classification were observed.

For all 3 victimization conduct behaviors associated with *recent TBI* adjusted odds ratios were significant. With the addition of current hazardous drinking to recent TBI, the adjusted odds-ratios associated with perpetrator reports of conduct behavior were statistically significant on 10 of the 13 measures compared to individuals in the baseline membership class (neither conditions). With the addition of hazardous drinking to recent TBI, compared to the baseline classification , the adjusted odds-ratios associated with all 3 measures of conduct behavior victimization were statistically significant. The adjusted odd ratios of perpetration of conduct behaviors associated with hazardous drinking was statistically significant for all of the 12 measures.

Comparing the individual versus combined effects of TBI and problem drinking

Table 5 summarizes analyses designed to highlight the incremental impact of experiencing co-occurring TBI and hazardous drinking compared to either condition by itself (referent). The analysis also included those with no history of TBI or hazardous drinking. Comparisons between the three groups revealed significantly higher adjusted odds ratios that ranged between 2.17 to 2.98 on all 6 mental health measures for students who experienced both conditions in comparison to those who experienced one. Students who reported both conditions (TBI and co-occurring hazardous drinking) had significantly higher adjusted odds of mental health problem indicators on measures of psychological distress, use of medication for depression or anxiety, contemplating suicide in the past 12 months, attempting suicide in the past 12 months, and fair or poor self-reported mental health. The two groups did not differ on three mental health measures (called a crisis or help line, used prescribed medication for ADHD, reporting fair or poor general health). Compared to students who experienced one condition (had

history of TBI or screened positive for hazardous drinking), students reporting neither had significantly lower adjusted odds of mental health problem indicators on seven of the eight measures. The only exception was that the groups did not differ on self-reported general health.

For measures of perpetration (Table 5), students who reported co-occurring TBI and hazardous drinking had significantly higher adjusted odds of reporting taking a car without permission, damaging property, selling cannabis, stealing more than $50, beating up or hurting someone, breaking into a locked building, carrying a weapon, setting a fire, fighting on school property, and bullying others at school. The two groups did not differ on the adjusted odds of taking things worth less than $50 and running away from home. Compared to the group reporting one condition (TBI or hazardous drinking), those reporting neither had significantly lower adjusted odds on all measures of perpetration. For measures of victimization, those reporting both conditions (TBI and co-occurring hazardous drinking) had significantly higher adjusted odds of being threatened with a weapon and being bullied on the internet, but did not differ on odds of being bullied at school. Those reporting neither conditions (never had TBI and failed to score positive for hazardous drinking), compared to the group reporting one of the two conditions (TBI or hazardous drinking), had significantly lower adjusted odds on all three measures of victimization.

Discussion

In this population of Ontario high school students, one in eight reported *former TBI* (incurred during lifetime but not in the past 12 months) and were not current

drinkers; one in 25 were identified as hazardous drinkers with co-occurring recent TBI; one in 7 were identified as hazardous drinkers and had no history of TBI; one in 24 were identified as hazardous drinkers with co-occurring history of former TBI; and one in 45 were identified as hazardous drinkers with co-occurring recent TBI. In our sample, group membership did not vary by sex, but did vary by age, as measured by school grade. Significant odds ratios emerged for hazardous drinking with co-occurring history of former TBI among grade 10, 11 and 12 students compared to those in grade 9. Odds ratios were three times higher for hazardous drinking with co-occurring recent TBI among grade 12 compared to grade 9 students. Odds ratios were 3.5 and 6 times higher for hazardous drinking among grade 11 and 12 students, respectively, compared to grade 9 students. These differences mirror patterns of such differences in the adolescent population reported previously.[4,18-21,33,36] These results show the emergence of hazardous drinking over the high school years, and suggest that this emergence may occur at an elevated rate among those with former and current TBI.

Since we were unable to find previous studies examining the co-occurrence of hazardous drinking and TBI in a representative sample of adolescents, there is no study to compare our estimates. However, adult studies have shown that among individuals currently in rehabilitation for substance abuse the rates of co-occurring history of TBI ranged between 38% to 63%.[37-38] We found that of all students screening positive at the time of testing for hazardous drinking, 32.4% also reported a history of TBI, which approaches the range observed in these adult studies, and confirms the notable existence of the TBI-alcohol co-occurrence.

Associations between TBI, problem drinking and current mental health issues

The results we report here replicate and extend previous results on the individual impact of hazardous drinking and TBI on mental health indicators.[19-20] Odd ratios among current hazardous drinkers were significantly higher for elevated psychological distress, being prescribed medication for anxiety, depression or both, being prescribed medication for ADHD, suicidal ideation, suicide attempt, and self-rated fair or poor mental health in the past 12 months. Previous research has shown that depression, anxiety, ADHD, or combinations of these conditions are risk factors for hazardous drinking among adolescents because some youth use drinking as a coping strategy for dealing with internal distress.[39-41] Evidence also shows that adolescents diagnosed with mental disorders including anxiety, depression and ADHD have significantly elevated rates of alcohol problems.[42-43]

Adjusted odds ratios were significantly higher among adolescents who reported *former TBI* (*but not recent TBI*) for being prescribed medication for anxiety, depression or both, being prescribed medication for ADHD, suicidal ideation, suicide attempt, reporting fair or poor mental health, and calling a crisis line for help compared to adolescents who never had a TBI and were not problem drinkers. These results replicate findings linking these mental health issues to long term history of TBI.[44-45] These results suggest that *recent TBI* without hazardous drinking does not increase the odds of the mental health issues assessed here, with the exception of suicide attempts. Specifically, adolescents who reported *recent TBI* had 9 times higher adjusted odds of reported attempted suicide in the past 12 months, than those who never had a TBI and were not identified as hazardous drinkers. Suicide is the third leading cause of death among people between the ages of 14 and 25, and has recently been identified as a condition

that is linked with both TBI and hazardous drinking.[25,46-47] A recent systematic review of studies published between 2007-2012 revealed that the link between suicidal ideation and TBI was robust,[48] while a Canadian study of 235,000 adults found that adults with a history of concussions were three times more likely to die by suicide compared to individuals who never had a concussion.[46] Our results confirm that *former TBI, recent TBI,* and hazardous drinking are strongly related to suicidal ideation and suicide attempt in adolescents, and suggest that this link is intensified among adolescents experiencing both conditions. Furthermore, these results suggest that adolescents who are *hazardous drinkers and have recent TBI* show the largest odds-ratios of suicide attempts than adolescents who never had a TBI and are not problem drinkers, compared to the rest of the TBI-AUDIT classifications we examined. Therefore, it is important to be aware of the risk of suicide ideation and attempt associated with excessive alcohol use among youth who recently had a TBI, as well as the attitudes that these messages engender in adolescents with regards to self-inflicted harm. Overall these results point to the urgent need for combined prevention efforts in school for TBI, alcohol use, and suicide.

Hazardous drinkers with *recent TBI* had more and higher odd ratios for most current mental health behaviors than hazardous drinkers with *former TBI*. To our knowledge this is the first time when temporarily interpretable patterns of association such as these have been demonstrated in a population based study. However, given the correlational nature of our design we cannot draw causal inferences. It is therefore unclear whether mental health issues, such as the ones examined here, represent immediate consequences of recent TBI that co-occur with problem drinking which, with the passage of time, may decrease in their odd ratios due to their identification and

treatment (e.g., prescribed medication, counselling, etc.), or risks for the TBI problem drinking co-occurrence. Previous research evidence suggests that the increase in mental health issues in the first year post TBI with problem drinking is not uncommon. For example, depression is about 8 times more common after TBI in the first year post-injury when co-occurring with increased alcohol consumption, among adults.[49] Alcohol post TBI, short and long term, can interfere with prescribed medication leading to overdose, multiplying effects (alcohol plus other medication effects), or death.[49-50] Furthermore, it is important to recognize that adolescents who consume alcohol are also more likely to use other substances and vice versa, particularly among TBI survivors.[4,20] Given that many adolescents are involved not only with alcohol but also with other substances and may have a mental disorder and TBI, interventions should be designed to address these complexities. Taken together, these results demonstrate that whether the TBI occurred recently (past year) or previously (more than a year ago) including its occurrence and considering its contribution in the management of mental health conditions and rehabilitation efforts may be an important consideration for clinicians.

Associations between TBI, problem drinking and current conduct behaviours

Adolescents who classified as *hazardous drinkers with former TBI* had numerous and higher odds ratios for conduct behaviours than *hazardous drinkers with recent TBI*. These results may suggest that the odds ratios of behavioural issues long term increases rather than subside, as one may expect. On the other hand, these results are not surprising if TBI is accompanied by other comorbid conditions (e.g. hazardous drinking, mental health issues, etc.). On the other hand, some researchers found that conduct problems related to TBI often do not appear until several months or years

following an injury unless the TBI is more severe.[51-52] TBI sustained during youth can lead to sustained and persistent impaired functioning in many areas, including neurologic, neuromuscular, neurocognitive, and neuropsychiatric.[51] The extent of these deficits is not fully understood or evident immediately after the injury. Post injury problems with impulsivity, difficulty paying attention and focused attention, and restlessness post TBI is common in about one third of youth.[53] Older children and adolescents have more problems inhibiting behavior that may be expressed through impatience, irritability, aggression and inappropriate comments[54] and may act on an impulse that could have been ignored before the injury. With the addition of alcohol use and other comorbidities behavioral issues, violence and aggression are not uncommon.[25,55]

A social ecological perspective suggests that several social contexts and the interdependencies of these contexts contribute to the development of adolescent hazardous drinking, risk behaviors leading to TBI, and alcohol misuse post TBI.[56-61] While adolescent problem drinking and TBI, especially sports injuries, have been recognized to be shaped by the socialization contexts and processes,[60] research on schools and neighborhoods is far less common than research on family and peer influences.[62] Yet they both contribute and perpetuate the socialization of co-occurring hazardous drinking and TBI. For example, aggressive play (seeking revenge on ice) in minor league hockey is often reinforced by the player's social environment and justified by players as a demonstration of loyalty to teammates and especially injured teammates.[56] The social context is particularly relevant to the population examined here since the main mechanism of injury among Ontario adolescents since 2011 has

remained sports injuries, particularly team sports (e.g., hockey, soccer, etc.).[19] While much of human behaviour is influenced by our genetic makeup, the socialization process can mold it in particular directions by encouraging specific beliefs and attitudes as well as selectively providing experiences.[58,60-62] The implication of the results we report here are important for prevention and monitoring, long term. It may be useful for teachers, sports coaches, and school guidance councilors to be made aware of students who have a history of TBI, and to maintain on-going communication with parents to prevent the development of harmful co-morbid conditions overtime.[58] Prevention efforts may want want to consider forming a means of facilitating parents, sports coaches, clinicians and school guidance councilors to work together as a team to provide support for the adolescent short and long term. The results of our study warrant the need for a greater understanding of the ways in which sports and alcohol misuse socialization combine to create, externally, a culture of violence and aggression, and internally, mental health issues. Physicians, health professionals, researchers, and concerned parents for their part, can help advocate for interventions that involve all levels of social context and processes (e.g., home, school, community); serve as role models for a healthy approach to sport and peer interactions and socialization; counsel players, parents and coaches, and school guidance councillors, and raise awareness about safe play and the risks associated with certain practices in sports.

This is the first population-based study to compare the individual impact of current hazardous drinking and history of TBI with their combined effects on mental health and conduct behaviors outcomes. The results provide strong support for the suggestion that the negative effects of the co-occurrence of hazardous drinking with TBI

may be synergistic. When hazardous drinking co-occurred with either *former or recent* TBI, the odds were significantly elevated for nearly all the mental health and perpetrator related violent and non-violent conduct behaviors, as well as reports of being the victim of being threatened with a weapon on school property or being bullied at school or via the internet, compared to reporting only TBI or hazardous drinking. The incremental impact of the co-occurrence of hazardous drinking and TBI has not previously been demonstrated, but it appears substantial.

Limitations

At the same time, readers should be mindful of our study's limitations. First, the results are based on self-report and thus subject to bias that may affect validity. Second, the data are obtained from a cross-sectional survey and thus do not allow causal conclusions to be drawn. While our post-survey assessment of substance use and mental health indicators did not show evidence of appreciable bias, the survey's student response rate (63%), while considered normative for such studies, may be subject to nonresponse bias.[4] Although most clinical literature has investigated the relationship between TBI and mental health symptoms post TBI, alcohol misuse and mental health problems may also be linked to risk-taking behaviors that precipitate TBI. Finally, our operational definition of TBI excluded milder forms of the injury that leaves the individual confused or dazed without loss of consciousness, or with a loss of consciousness for less than 5 minutes.

Conclusion

Nevertheless, these results are of substantial interest. First, the results not only replicate but extend findings that the joint occurrence of hazardous drinking and TBI

among adolescents is associated with significant adverse mental health and conduct behavior correlates. The incremental negative consequences of the co-occurrence of hazardous drinking and TBI in an adolescent population we report is novel. Additionally, whether the TBI occurred in the past year or previously may be an important consideration. Separation of *recent* from *former TBI* strengthens the ability to make causal interpretations. The TBI-AUDIT classifications are temporally interpretable (e.g., past history of TBI versus current hazardous drinking assessment). This study contributes to the slowly developing international population studies assessing alcohol misuse and TBI.

Our results suggest that, when dealing with adolescents with a drinking problem, it may be important to look for history of TBI, and conversely, when dealing with adolescents with TBI, it may also be important to look for evidence of hazardous drinking, as co-occurrence appears to be associated with substantially greater mental health problems and conduct behaviours. Additional research to understand the incremental problems experienced by those with co-occurring hazardous drinking and TBI, and to understand the causal relationships involved, is greatly needed. Such examinations are crucial in helping guide clinicians, physicians, prevention and rehabilitation programs.

Author contributions: Drs. Ilie and Mann had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analyses.

Study concept and design: Ilie, Mann, Boak, Hamilton, Rehm, Cusimano

Acquisition of data: Mann, Hamilton, Boak

Analysis and interpretation of data: Ilie, Mann, Boak, Adlaf

Drafting of the manuscript: Ilie

Critical revision of the manuscript for important intellectual content: Ilie, Mann, Boak, Hamilton, Rehm, Cusimano

Statistical analysis: Ilie, Mann

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Data availability:

No additional data available**.**

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Table 1. Covariates and predictors included in the analysis

Variable	*Definition*
Sex – covariate	Male, female
Grade – covariate	Four categories: 9th, 10th, 11th, 12th
Mental health measures	
Psychological distress	Moderate to high vs. low psychological distress in the past 4 weeks GHQ[25]
Used prescribed medication to reduce anxiety, depression, or both	Past 12 months taking prescribed medication for anxiety, depression or both (yes=1, 0 otherwise)
Suicidal ideation	Seriously considered suicide in the past 12 months (yes= 1, 0 otherwise)
Suicide attempt	Attempted to commit suicide in the past 12 months (yes=1, 0 otherwise)
Called a crisis or help line in past 12 months	Called a youth crisis or help line in past 12 months for help (yes= 1; 0 otherwise)
Used prescribed medication to treat ADHD	Past 12 month use of prescribed medication to treat ADHD (yes=1, 0 otherwise)
Self-rated mental health status	Reported excellent/ good mental health vs. fair or poor mental health (yes=1; 0 otherwise)
Self-rated health status	Reporting excellent/ good health vs. fair or poor health in general (yes=1; 0 otherwise)
Violent and non-violent conduct behaviors (perpetrator or victim)	
Drove a car without the owner's permission	Taken the car for a ride without the owner's permission at least once in the past 12 month (yes=1; 0 otherwise)

Damage to property	Damaged something on purpose that did not belong to you at least one in past 12 months (yes=1; 0 otherwise)
Sold marijuana or hashish at school	Sold marijuana or hashish at least once in the past 12 months (yes=1; 0 otherwise)
Stealing (things worth 50$ or less)	Taken things worth $50 or less at least once in the past 12 months (yes=1; 0 otherwise)
Stealing (things worth more than 50$)	Taken things worth $50 or more at least once in the past 12 months (yes=1; 0 otherwise)
Physical violence (in purpose)	Beat up, hurt anyone in purpose at least once in the past 12 months (yes=1; 0 otherwise)
Physical violence at school	Engaged in a physical fight on school property at least once in past 12 months (yes=1; 0 otherwise)
Breaking into property	Times broken into a locked building other than one's own at least once in the past 12 months (yes=1; 0 otherwise)
Possession of a weapon (e.g., gun, knife) on school property	Carried a weapon such as a gun or a knife at least once in the past 12 months (yes=1; 0 otherwise)
Running from home	Ran away from home in the past 12 months (yes=1; 0 otherwise)
Set fire	Set something on fire you weren't supposed to at least once in the past 12 months (yes=1; 0 otherwise)
Bullied others	Bullied others at school at least once in the past 12 months (yes=1; 0 otherwise)
Being threatened with a gun or weapon at school (*Victim*)	Was threatened with a gun or a weapon on school property in the past 12 months (yes=1; 0 otherwise)
Being bullied at school (*Victim*)	Been bullied at school at least once in the past 12 months

	(yes=1; 0 otherwise)
Being bullied through the internet (*Victim*)	Been bullied through the internet once in the past 12 months (yes=1; 0 otherwise)

Table 2. Descriptive analyses predicting membership classification: TBI former (lifetime but not past 12 months; no current hazardous drinking); TBI recent (past 12 months; no current hazardous drinking), Hazardous Drinking (never had TBI), former TBI with co-occurring Hazardous Drinking (no recent TBI), recent TBI recent with co-occurring Hazardous Drinking, and base category (no TBI or Hazardous Drinking) by demographics, among adolescents grades 9 through 12, Ontario, Canada, 2013, n=3130

	Base category % (95% CI) OR (95% CI) n=2082	Former TBI (no Hazardous Drinking) % (95% CI) OR (95% CI) n=367	Recent TBI (no Hazardous Drinking) % (95% CI) OR (95% CI) n=104	Hazardous Drinking (no TBI) % (95% CI) OR (95% CI) n=390	Former TBI & Hazardous Drinking % (95% CI) OR (95% CI) n=117	Recent TBI & Hazardous Drinking % (95% CI) OR (95% CI) n=70
Sex	F (5, 94) = 1.08					
Male	62.0 (57.4,66.5) 1.00 (Ref) n=864	12.6 (10.0,15.8) 1.23 (.85,1.78) n=187	4.4 (3.0,6.6) 1.31 (.67, 2.53) n=51	13.5 (11.6,15.7) 1.03 (.78,1.37) n=155	5.1 (3.1,8.4) 1.79 (.93,3.44) n=60	2.3 (1.4,3.8) 1.16 (.57,2.32) n=34
Female (Ref.)	66.3 (62.5,69.8) n=1218	11.0 (8.8,13.6) n=180	3.6 (2.2,6.0) n=53	13.9 (11.7, 16.6) n=235	3.1 (2.1, 4.4) n=57	2.1 (1.4, 3.1) n=36
Grade	F (15, 84)=14.37***					
12	72.1 (68.6,75.3) 1.00 (Ref.) n=458	14.8 (11.8,18.4) .84 (.52, 1.34) n=60	6.5 (4.4,9.5) .84 (.39, 1.79) n=22	4.8 (3.2,7.1) 6.35(4.16,9.69)*** n=162	0.8 (0.3,1.9) 11.75(4.03,34.27)*** n=46	1.1 (0.5,2.5) 3.07(1.16,8.15)** n=24
11	71.1 (65.9,75.7) 1.00 (Ref.) n=518	13.3 (10.0,17.4) .85 (.55, 1.30) n=88	2.4 (1.2,4.8) .58 (.32, 1.04) n=22	8.0 (4.9,12.8) 3.58(1.98,6.46)*** n=125	2.5 (1.3, 4.9) 7.88(2.96,20.95)*** n=35	2.8 (1.4,5.5) 2.47(.74,8.24) n=21
10	63.2 (57.4,68.6) 1.00 (Ref.) n=548	11.0 (8.2,14.5) .91 (.65, 1.28) n=110	3.3 (1.9,5.7) .37 (.18, .78) n=24	15 (11.1,19.9) 1.69 (.87,3.39) n=63	5.3 (3.7,7.4) 3.37(1.06,10.76)* n=22	2.4 (1.0,5.6) 2.57(.84,7.89) n=14
9 (Ref.)	54.4 (48.9,59.7) n=558	9.4 (6.9,12.6) n=109	4.1 (2.2,7.6) n=36	22.9 (19.6,26.5) n=40	6.7 (4.2,10.7) n=14	2.5 (1.6,3.8) n=11

Table 3. Multinomial Logistic Regression analyses predicting membership classifications: *Former TBI* (lifetime but not past 12 months; no current hazardous drinking); *Recent TBI* (past 12 months; no current hazardous drinking), *Hazardous Drinking (never had TBI)*, *Former TBI with co-occurring Hazardous Drinking* (no recent TBI), *Recent TBI recent with co-occurring Hazardous Drinking*, and *Base Category* (Ref.; no TBI or Hazardous Drinking) by mental health measures among adolescents grades 9 through 12, Ontario, Canada, 2013, n=3130

	Former TBI (n=367) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Recent TBI (n=104) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Hazardous Drinking (n=390) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Former TBI & Hazardous Drinking (n=117) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Recent TBI & Hazardous Drinking (n=70) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)
Moderate to high levels of psychological distress					
F (5,94) = 7.29***	1.17 (.80, 1.73)	1.15 (.54, 2.43)	1.49 (1.17, 1.90)**	3.10 (1.67, 5.75)***	2.14 (1.07, 4.30)*
F (15,84) = 9.80***	1.25 (.87, 1.81)	1.24 (.64, 2.40)	1.65 (1.29, 2.13)***	4.06 (2.21, 7.44)***	2.36 (1.11, 5.02)*
Past 12 months prescription medication for anxiety, depression or both					
F (5,94) = 6.36***	2.26(1.08,4.73)*	1.90 (.65, 5.55)	2.11 (1.13, 3.96)*	6.15 (2.75, 13.77)***	6.24 (2.73, 14.28)***
F (15,84) =11.80***	2.44 (1.18, .07)*	2.08 (.73, 5.86)	1.74 (.81, 3.73)	6.02 (2.59, 13.0)***	6.17 (2.64, 14.42)***
Past 12 months did you contemplate attempt suicide					
F (5,90) = 7.49***	1.65 (1.12,2.45)*	1.98 (.88, 4.49)	1.88 (1.31, 2.70)**	2.71 (1.29, 5.69)**	4.45 (1.90, 10.42)**
F (15,80) =11.80***	1.74(1.17,2.57)**	2.11 (.99, 4.47)	2.17 (1.50, 3.13)***	3.48 (1.62, 7.48)**	4.96 (2.07, 11.90) ***
Past 12 months did you actually					

attempt suicide F (5,90) = 15.93*** F (15,80) =14.29***	4.43(2.27,8.64)*** 4.81(2.48,9.35)***	8.14(2.68,24.73)*** 9.14(3.22,25.93)***	5.03 (2.64, 9.58)*** 6.45 (3.09, 13.48)***	6.36 (2.11, 19.14)** 9.70 (3.37, 27.96)***	24.77(9.10, 67.42)*** 31.23(10.29,94.82)***
Called a child crisis or help line in past 12 months F (5, 94) = 5.34*** F (15, 84)=9.77***	2.05(1.49, 6.26)** 3.26(1.58, 6.74)**	.32 (.08, 1.23) .34 (.09, 1.34)	2.12 (1.01, 4.43)* 2.11 (.99, 4.46)	3.20 (1.05, 9.70)* 3.75 (1.24, 11.33)*	5.49 (2.0, 15.08)** 5.80 (2.13, 15.80)**
Past 12 months used prescribed medication to treat ADHD F (5, 94) = 4.10** F(15,84)=11.32***	2.99 (1.32,6.79)** 2.88 (1.25, 6.59)*	5.39 (.97, 30.05) 5.12 (.93, 28.14)	2.86 (1.45, 5.62)** 2.99 (1.47, 6.06)**	5.23 (1.90, 14.37)** 5.00 (1.74, 14.41)**	7.29 (1.83, 29.01)** 7.33 (1.90, 28.30)**
Reporting fair or poor mental health in general F (5, 94) = 5.18*** F (15, 84) =8.79***	1.53 (1.03, 2.28)* 1.61 (1.10, 2.36)*	1.30 (.58, 2.87) 1.38 (.68, 2.80)	1.31 (.98, 1.77) 1.40 (1.02, 1.91)*	3.37 (1.71, 6.64)** 3.93 (2.03, 7.61)***	2.85 (1.42, 5.74)** 3.07 (1.46, 6.44)**
Reporting fair or poor health in general F(5, 94) = .20 F(15, 84)=10.83***	.98 (.59, 1.64) .99 (.59, 1.66)	1.10 (.38, 3.17) 1.11 (.39, 3.18)	1.15 (.63, 2.10) 1.12 (.62, 2.04)	1.40 (.61, 3.20) 1.40 (.63, 3.12)	1.25 (.33, 4.65) 1.23 (.34, 4.48)

Notes: F - design adjusted Wald F tests; Odds Ratios (OR) and Adjusted Odds Ratios (AOR) were calculated using logistic regression. AORs were evaluated while holding fixed values of the complexity of the design, sex and grade; *** P < 0.001; ** P < 0.01; * P<0.05

Table 4. Multinomial Logistic Regression analyses predicting membership classifications: *Former TBI* (lifetime but not past 12 months; no current hazardous drinking); *Recent TBI* (past 12 months; no current hazardous drinking), *Hazardous Drinking (never had TBI)*, *Former TBI with co-occurring Hazardous Drinking* (no recent TBI), *Recent TBI recent with co-occurring Hazardous Drinking*, and *Base Category* (Ref.; no TBI or Hazardous Drinking) by conduct behaviours among adolescents grades 9 through 12, Ontario, Canada, 2013, n=3130.

	Former TBI (n=367) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Recent TBI (n=104) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Hazardous Drinking (n=390) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Former TBI & Hazardous Drinking (n=117) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Recent TBI & Hazardous Drinking (n=70) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)
Taken the car for a ride without the owner's permission					
F (5,94)=26.32***	2.14 (.95, 4.82)	4.29 (1.35, 13.65)*	6.48(4.02,10.43)***	17.92 (9.57, 33.55)***	3.17 (.97,10.39)
F (15,84)=14.52***	2.17 (.97, 4.88)	4.27 (1.33, 13.69)*	5.61 (3.53, 8.94)***	15.15 (7.77, 29.56)***	2.93 (.87, 9.93)
Damaged something on purpose					
F (5,94)=14.57***	1.46 (.89, 2.38)	6.21(2.76,13.98)***	2.72 (1.65, 4.49)***	5.50 (2.50, 12.07)***	9.29(4.44,19.44)***
F (15,84)=21.56***	1.42 (.87, 2.33)	6.13 (2.67, 14.06)***	3.14 (1.86, 5.29)***	6.16 (2.65, 14.31)***	9.98 (4.65, 21.44)***
Sold marijuana or hashish					
F (5.94)=31.48***	2.51 (1.26, 5.02)*	10.16 (3.22,32.06)***	12.11 (6.86,21.36)***	29.29 (16.63,51.58)***	8.82 (3.25, 23.97)***
F(15,84)=18.00***	2.41 (1.74, 4.95)*	9.80(3.21,29.94)***	13.35 (6.37,27.98)***	29.71 (14.88,59.31)***	9.02 (2.86, 28.45)***
Taken things worth $50 or less					
F (5,94)=19.02***	2.07 (1.31, 3.25)**	2.18 (1.06, 4.45)*	5.17 (3.18, 8.39)***	6.92 (4.02, 11.91)***	2.59 (.78, 8.54)
F (5,84)=20.06***	2.04 (1.30, 3.22)**	2.12 (1.02, 4.12)*	5.31 (3.43, 8.22)***	6.69 (3.86, 11.59)***	2.57 (.78, 8.49)
Stealing more than $50					
F (5,94)=11.28***	1.62 (.59, 4.47)	2.83 (.86, 9.33)	7.77 (3.39, 17.82)***	15.17 (5.93, 38.84)***	8.13 (2.41, 27/36)**

F (15,84)=13.97***	1.62 (.58, 4.54)	2.75 (.83, 9.12)	7.05 (2.96, 16.81)***	12.88 (4.70, 35.30)***	7.61 (2.24, 25.87)**
Beat up, hurt anyone in purpose					
F (5,94)=18.08***	2.40 (1.22, 4.75)*	4.34 (1.84, 10.20)**	4.97 (2.71, 9.10)***	9.61 (4.93, 18.73)***	8.64 (2.98, 25.04)***
F (15,84)=17.64***	2.31 (1.15, 4.64)*	4.18 (1.77, 9.84)**	5.98 (3.16, 11.32)***	11.06 (5.26, 23.24)***	9.40 (3.19,27.66)***
Broken into a locked building other than one's own					
F (5,94)=20.49***	.48 (.18, 1.30)	1.92 (.59, 6.26)	4.81 (2.31, 10.05)***	8.70 (3.83, 19.78)***	9.43 (2.84, 31.34)***
F (15,84)=10.72***	.48 (.18, 1.26)	1.85 (2.08, 6.46)	4.79 (2.08, 11.05)***	8.01 (3.12, 20.62)***	9.26 (2.59, 33.13)***
Carried a weapon such as a gun or a knife					
F (5,94)=13.767***	5.13 (2.81,9.35)***	6.66 (2.75, 16.10)***	5.67 (2.82, 11.38)***	9.99 (4.85, 20.57)***	9.21 (3.57, 23.74)***
F (15,84)=29.00***	4.92 (2.69,8.97)***	6.40 (2.35, 17.43)***	7.67 (3.95, 14.90)***	12.73 (5.79, 27.99)***	10.71(4.06,28.20)***
Run away from home					
F (5,94)=13.67***	1.76 (.99, 3.13)	3.67 (2.30, 5.84)***	4.16 (2.56, 6.77)***	4.85 (2.01, 11.73)**	4.49 (1.57, 12.86)**
F (15,84)=12.60***	1.78 (.99, 3.16)	3.78 (2.44, 5.86)***	4.55 (2.82, 7.33)***	5.79 (2.16, 15.52)**	4.74 (1.59, 14.17)**
Set fire					
F (5,94)=14.58***	1.47 (.94, 2.29)	3.04 (1.26, 7.35)*	4.00 (2.69, 5.92)***	6.07 (3.03, 12.16)***	3.54 (1.36, 9.20)*
F (15,84)=24.63***	1.40 (.92, 2.14)	2.96 (1.17, 7.46)*	5.34 (3.41, 8.37)***	7.88 (3.77, 16.47)***	4.02 (1.59, 10.15)**
In a physical fight on school property					
F (5,94)=6.65***	2.36 (1.42, 3.92)**	6.59 (2.77, 15.68)***	1.98 (.96, 4.11)	4.91 (2.26, 10.68)***	4.21 (1.55, 11.46)**
F (15,84)=15.92***	2.25 (1.38, 3.66)**	6.78 (2.70, 17.01)***	2.50 (1.14, 5.49)*	5.62 (2.28, 13.83)***	4.77 (1.77, 12.86)**
Bullied others at school					
F (5,94)=10.05***	1.52 (1.00, 2.32)	1.56 (.54, 4.50)	2.12 (1.40, 3.20)***	4.54 (2.62, 7.85)***	3.81 (1.85, 7.83)***
F (5,84)=14.74***	1.48 (.98, 2.25)	1.52 (.52, 4.49)	2.50 (1.61, 3.89)***	5.24 (2.93, 9.37)***	4.11 (2.05, 8.26)***
Was threatened with a gun or a weapon					

(VICTIM) F (5,94)=9.20*** F (5,84)=17.53***	2.72 (1.42, 5.24)** 2.61 (1.37, 4.95)**	7.35 (2.39, 22.60)** 7.12 (2.35, 21.55)**	2.48 (1.27, 5.29)* 2.90 (1.29, 6.52)*	7.19 (2.18, 16.25)*** 7.97 (3.25, 19.55)***	6.72 (2.64, 17.16)*** 7.20 (2.87, 18.08)***
Been bullied at school (VICTIM) F (5,94)=3.33** F (5,84)=9.41***	1.63 (1.15, 2.31)* 1.63 (1.16, 2.28)*	2.04 (1.06, 3.95)* 2.08 (1.12, 3.87)*	1.24 (.88, 1.74) 1.52 (1.08, 2.15)*	2.07 (1.00, 4.30) 2.77 (1.34, 5.71)**	2.44 (1.20, 4.95)* 2.77 (1.37, 5.57)**
Been bullied through the internet (VICTIM) F (5,94)=6.73*** F (5,84)=12.34***	1.55 (1.03, 2.34)* 1.56 (1.03, 2.38)*	3.22 (1.47, 7.10)** 3.36 (1.48, 7.64)**	1.48 (.99, 2.22) 1.76 (1.18, 2.64)**	3.29 (1.80, 6.02)*** 4.17 (2.18, 7.98)***	WHl2.64 (1.22, 5.70)* 2.94 (1.20, 6.64)*

Notes: F - design adjusted Wald F tests; Odds Ratios (OR) and Adjusted Odds Ratios (AOR) were calculated using logistic regression.

aORs were evaluated while holding fixed values of the complexity of the design, sex and grade; *** P < 0.001; ** P < 0.01; * P<0.05

Table 5. Multinomial Logistic Regression analyses predicting membership classifications by history of TBI and Hazardous Drinking: either History of TBI or Hazardous Drinking, separately; no History of TBI or Hazardous Drinking; co-occurring History of TBI with current Hazardous Drinking for mental health and conduct behaviors measures, n=3130

	No history of TBI or hazardous drinking (n=2082) vs. History of TBI or Hazardous Drinking (n=881) OR (95% CI) AOR (95% CI)	History of TBI with hazardous drinking (n=187) vs. History of TBI or Hazardous Drinking (n=881) OR (95% CI) AOR (95% CI)
Mental health measures		
Moderate to high levels vs. low levels of psychological distress		
F (2,352) = 24.11***	.68 (.55, .85)***	2.26 (1.51,3.39)***
F (2,355) = 24.27***	.66 (.53, .82)***	2.42 (1.16, 3.63)***
Past 12 months prescription medication for anxiety, depression or both		
F (2,181) = 6.36***	.46 (.26,.84)***	2.89 (1.63,5.12)***
F (2,180) = 12.60***	.49 (.26, .92)***	2.98 (1.68, 5.29)***
Past 12 months did you contemplate attempt suicide		
F (2,339) = 17.82***	.57 (.44,.75)***	1.95 (1.19,3.17)*
F (2,333) = 19.99***	.53 (.40,.70)***	2.17 (1.21,3.58)***
Past 12 months did you actually attempt suicide		
F (2,327) = 25.34***	.26 (.17,.41)***	2.39 (1.21,4.72)***
F (2,306) = 28.17***	.23 (.15,.35)***	2.95 (1.39,6.26)***
Called a child crisis or help line in past 12 months		
F (2,355) = 10.98***	.34 (.28,.68)***	1.65 (.82,3.32)
F (2,349) = 12.32***	.40 (.26, .62)***	1.81 (.86,3.79)
Past 12 months used prescribed medication to treat ADHD		
F (2,346) = 12.11***	.32 (.18, .58)***	2.01 (.85, 4.72)
F (2,346) = 10.54***	.32 (.18,.57)***	2.04 (.82,5.05)
Reporting fair or poor mental health in general vs.		

excellent/ good mental health F (2,318) = 21.10*** F (2,312) = 22.03***	.63 (.51,.68)*** .61 (.50, .75)***	2.33 (1.42, 3.84)*** 2.44 (1.48,4.03)***
Reporting fair or poor health in general vs. excellent/ good health F(2,302) = .91 F (2,336) = .81	.80 (.51,1.24) .80 (.50,1.28)	1.15 (.55,2.38) 1.16 (.57, 2.34)
Conduct behaviours		
Taken the car for a ride without the owner's permission F (2,320)=46.22*** F (2,329)=31.17***	.21 (.13,.34)*** .26 (.16,.41)***	3.04 (1.95,4.76)*** 2.49 (1.54,4.03)***
Damaged something on purpose F (2,352)=33.68*** F (2,348)=32.07***	.42 (.30,.59)*** .41 (.29,.58)***	2.85 (1.75,4.65)*** 3.00 (1.78,5.08)***
Sold marijuana or hashish F (2,329)=43.92*** F(2,340)=34.01***	.14 (.08,.26)* .17 (.09,.30)*	3.11 (1.78,5.46)*** 2.76 (1.52,5.00)***
Taken things worth $50 or less F (2,355)=48.78*** F (2,350)=41.12***	.29 (.22,.39)*** .32 (.24,.42)***	1.76 (1.12,2.76)*** 1.59 (.99,2.54)
Stealing more than $50 F (2,356)=24.93*** F (2,356)=18.19***	.22 (.12,.42)*** .26 (.14,.49)***	3.20 (1.59,6.44)*** 2.71 (1.31,5.62)***
Beat up, hurt anyone in purpose F (2.253)=35.61*** F (2,253)=33.70***	.29 (.19,.433)*** .28 (.18,.42)***	2.54 (1.46,4.41)*** 2.76 (1.54,4.95)***
Broken into a locked building other than one's own F (2,355)=25.58*** F (2,355)=15.39***	.33 (.17,.64)*** .38 (.19,.75)***	4.41 (2.19,8.89)*** 1.85 (1.18,2.53)***
Carried a weapon such as a gun or a knife F (2,326)=32.61*** F (2,334)=33.92***	.21 (.12,.35)*** .20 (.12,.33)***	2.08 (1.16,3.74)*** 2.34 (1.23,4.44)***
Run away from home F (2,326)=22.81***	.33 (.24,.46)***	1.72 (.89,3.34)

F (2,307)=18,15***	.33 (.24,.47)***	1.75 (.84,3.66)
Set fire F (2,340)=22.86*** F (2,345)=27.65***	 .43 (.30,.62)*** .41 (.29,.58)***	 1.95 (1.22,3.10)*** 2.17 (1.35,3.49)***
In a physical fight on school property F (2,349)=18.53*** F (2,343)=25.03***	 .46 (.32,.65)*** .39 (.28, .54)***	 1.77 (1.07,2.94)* 2.11 (1.21,3.71)**
Bullied others at school F (2,354)=23.23** F (2,354)=26.61***	 .64 (.50,.82)*** .61 (.48,.79)***	 2.55 (1.63,3.97)*** 2.79 (1.77,4.39)***
Was threatened with a gun or a weapon (VICTIM) F (2,329)=16.37*** F (2,325)=18.27***	 .39 (.25, .61)*** .37 (.24,.57)***	 2.25 (1.06,4.77)* 2.45 (1.12,5.36)**
Been bullied at school (VICTIM) F (2,346)=7.97*** F (2,344)=16.93***	 .67 (.54,.84)*** .57 (.45,.71)***	 1.31 (.79,2.18) 1.65 (1.01,2.73)
Been bullied through the internet (VICTIM) F (2,354)=23.23** F (2,347)=18.66***	 .60 (.46,.78)*** .53 (.41,.69)***	 1.71 (1.02,2.88)* 1.99 (1.16,3.43)***

Notes: F - design adjusted Wald F tests; Odds Ratios (OR) and Adjusted Odds Ratios (AOR) were calculated using logistic regression. AORs were evaluated while holding fixed values of the complexity of the design, sex and grade; *** P < 0.001; ** P < 0.01; * P<0.05

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

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Provided-p2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Provided-p2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported Provided-p.5-6
Objectives	3	State specific objectives, including any pre-specified hypotheses Provided-p6
Methods		
Study design	4	Present key elements of study design early in the paper Presented-p.6-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection Provided in methods-p6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants Provided in methods-p6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable Provided in methods-p.7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group Provided in methodsp.8-9
Bias	9	Describe any efforts to address potential sources of bias Provided in discussion=p.16
Study size	10	Explain how the study size was arrived at Provided in methods-p.9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why Provided-p.7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding √-p9
		(*b*) Describe any methods used to examine subgroups and interactions √-p.12
		(*c*) Explain how missing data were addressed √p.9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy √p.8-9
		(*e*) Describe any sensitivity analyses - n/a
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed – Provided-p.9, also Tables 1-5 provide ns.,

		p.25-
		(b) Give reasons for non-participation at each stage – n/a
		(c) Consider use of a flow diagram – n/a
Descriptive data	14*	(a) Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders – Provided plus online link to supplementary methods of the sample-p.6-7
		(b) Indicate number of participants with missing data for each variable of interest – p.9, plus on-line link in methods p.7
Outcome data	15*	Report numbers of outcome events or summary measures – Provided-Table 1-p.25
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included – Provided- Tables 1-5, p25-37
		(*b*) Report category boundaries when continuous variables were categorized – n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – n/a
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses – n/a
Discussion		
Key results	18	Summarise key results with reference to study objectives – Provided- p.3, p.13-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias – Provided-p.16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – Provided-p.16
Generalisability	21	Discuss the generalisability (external validity) of the study results – Provided-p.16-17
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based – Provided-p.18

*Give information separately for exposed and unexposed groups.

BMJ Open

A cross-sectional examination of the association of co-occurring alcohol misuse and traumatic brain injury on mental health and conduct problems in adolescents in Ontario, Canada.

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Running head: Comorbid health correlates of TBI and hazardous drinking among adolescents

A cross-sectional examination of the association of co-occurring alcohol misuse and traumatic brain injury on mental health and conduct problems in adolescents in Ontario, Canada.

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ABSTRACT

Objective: This study describes the impact of traumatic brain injury (TBI) and hazardous drinking on mental health and behavioral issues among Ontario adolescents. In particular, we assessed the incremental co-occurrence of hazardous drinking with history of TBI, in comparison to experiencing just one of these conditions.

Method: A cross-sectional subsample of 3130 Ontario adolescents attending grades 9 through 12, ages 10 through 21 were surveyed in 2013 as part of the Centre for Addiction and Mental Health's Ontario Student Drug Use and Health Survey. *Recent* (past year) and *former* (lifetime, excluding last year) TBI were defined as trauma to the head that resulted in loss of consciousness for at least five minutes or overnight hospitalization. Current hazardous drinking was derived using the Alcohol Use Disorders Identification Test (AUDIT).

Results: An estimated 11.8% (95% CI: 10.1, 13.8) reported a history of *former* TBI and were not hazardous drinkers; 4.0% (95% CI: 2.9, 5.5) reported *recent* TBI and were not hazardous drinkers; 13.7% (95% CI: 12.3, 15.3) were hazardous drinkers who never had a TBI; 4.1% (95% CI: 2.9, 5.8) had *former* TBI with co-occurring hazardous drinking; and 2.2% (95% CI: 1.6, 3.0) had *recent* TBI with co-occurring hazardous drinking. Most odds increased significantly and were between 2 to 3 times higher for reporting compromised mental health, violent and non violent conduct behaviors, and reported victimization for classifying as hazardous drinker at the time of testing with co-occurring either *former* or *recent* TBI compared to classifying as not having either of these conditions. Adolescents classified as hazardous drinkers with *former* TBI had

numerous and higher odd ratios for conduct behaviors than hazardous drinkers with *recent* TBI.

Conclusion: Results emphasize the strong interplay between TBI and hazardous drinking, and point to the need for integrating prevention efforts to reduce these conditions and their co-occurrence among adolescents.

ARTICLE SUMMARY

Strengths and limitations of this study:

- The study shows that the emergence of hazardous drinking over the high school years may occur at an elevated rate among adolescents with traumatic brain injury (TBI).
- This is the first time when temporarily interpretable patterns of association between hazardous drinking and history of TBI among adolescents were examined in the context of co-occurring mental health and problem behaviours in a population based study.
- Adolescents who classified as hazardous drinkers at the time of testing, with *former* lifetime history of TBI (that occurred prior to past 12 months), had numerous and higher odd ratios for conduct behaviors than hazardous drinkers with r*ecent* TBI (that occurred in the past 12 months).
- Hazardous drinkers with *recent TBI* had more and higher odd ratios for most mental health behaviors than hazardous drinkers with *former TBI*.
- These results demonstrate that whether the TBI occurred recently (past year) or previously (prior to last year) may be an important consideration for

management for these conditions and rehabilitation efforts.

- Possible bias related to self-report procedures and the preclusion of causal inferences due to the cross-sectional nature of the data are limitations of this study.
- Even though our data did not present evidence of appreciable bias overall, nonresponse bias may exist.

KEYWORDS: Traumatic brain injury, hazardous drinking, mental health, violence, adolescents

Introduction

Excessive drinking in adolescence can cause substantial harm to individuals, and is associated with future alcohol-related problems.[1-3] Drinking in adolescence is particularly risky because it is much more likely to be heavy and episodic (binge).[4-5] Excessive drinking during adolescence, while the brain is still developing, can be a major cause of trauma, physical injuries, hospitalization, prolonged disability and premature death.[1-3,6] Alcohol contributes substantially to motor vehicle collisions, homicides, suicide, assault, sexual risk-taking, and many other problems in Canada and the US.[7-16]

Hazardous drinking is both a contributor to and a consequence of traumatic brain injury (TBI).[17-18] Traumatic brain injuries (TBI) occur when a sudden trauma (hit or blow to the head) causes damage to the brain. An estimated one in 5 adolescents in Ontario has experienced TBI in their lifetime, and one in 18 has experienced it during the past 12 months.[19-20] Hospitalization data revealed that almost half of the individuals presenting with brain injuries were intoxicated upon hospital admission, and among adolescents and adults who required inpatient rehabilitation post TBI, over 60% were found to have had a history of alcohol or other drug misuse.[21-23] Adolescents who had experienced one or more TBIs in their lifetime had odds twice as much, to screen positive for current hazardous drinking or for reporting binge drinking in the past 12 months, compared to those who never had a TBI.[20]

Both TBI and hazardous drinking are relatively common among adolescents[4,19,20] and both have been linked with poor academic performance, mental health issues including suicide, and increased violent and non-violent conduct

behaviors.[19,24-29] Several studies using imaging methods have noted negative additive effects of alcohol misuse and TBI, such as brain atrophy over time and reduced reaction times.[30-32]

However, no studies have compared the separate and joint effects of hazardous drinking and TBI in general population or clinical samples of adolescents. Specifically, although previous research shows that both hazardous drinking and a history of TBI are associated with harmful health outcomes, that include mental health and behavioral issues, the incremental impact of having both of these conditions is unknown.[4,19-20,25-32] This study examines the association of history of TBI and hazardous drinking, separately and jointly, with past year mental health and conduct behaviors in a large representative sample of high school adolescents, in Ontario.

Methods

Data were based on a subsample of 3264 students in grades 9 to 12 and were derived from the 2013th cycle of the Centre for Addition and Mental Health's (CAMH) Ontario Student Drug Use and Health Survey (OSDUHS), a biennially repeated cross-sectional probability survey of Ontario students enrolled in four provincially-funded jurisdictions (Public vs. Catholic; English vs. French). In 2013, students were recruited from 198 schools and 671 classes dispersed province wide. Schools excluded from sampling were private, military, and institutional schools. With these exclusions our sample captures 92% of all Ontario children and adolescents aged 12 to 18.

Students completed self-administered, anonymous pen-and-paper questionnaires in their classrooms between November 2012 and June 2013. Participation rates were 61% for schools, 87% for classes, and 63% for students. A comparison between high (≥

70%) and low responding classes showed no evidence of nonresponse bias for a number of health-relate behaviours including TBI and the AUDIT.[4] Students completed one of two questionnaires (Form A or Form B) alternately distributed (i.e., A, B, A) within each class. Although the TBI items were asked of all students using forms A and B, because the AUDIT screener was contained in form A only, the estimation samples were reduced from 6159 to 3264 students. Detailed description of the sampling design and survey procedures is web-available.[4,33] The study was approved by the Research Ethics Committees of the Centre for Addiction and Mental Health (CAMH), St. Michael's Hospital (SMH), participating Ontario Public and Catholic school boards, and York University, which administered the surveys. All participants provided their assent in addition to parentally signed consent for those aged under 18.

Measures

Group membership categorization.

Our key analytical measure was derived from hazardous drinking and history of TBI. Hazardous or harmful drinking was derived using the 10-item AUDIT screener, a well-validated instrument assessing drinking frequency, volume, heavy consumption and indicators of abuse and dependence due to alcohol.[34] A cut score at or above 8 of 40 indicates a pattern of hazardous or harmful drinking.[35]

Traumatic brain injury (TBI) was based on two questions that asked students if they ever had a blow or a hit to the head that rendered them unconscious for at least five minutes or resulted in their hospitalization for at least one night. This criteria is also employed in diagnostic classification systems including DSM-IV and has previously been used in adolescent and adult studies.[36] Students were then asked if they ever had

such injury in the 12 months prior (recent TBI) or in their lifetime, but not in the 12 months prior (former TBI). Our analytic variable was formed by cross-tabulating these two measures to create out a 6-class membership variable.

Mental health problems, conduct behaviors and covariates are summarized in Table 1. The first set of analyses (Tables 2 through 4) were based on the following 6 levels classifications. The baseline classification included adolescents who never had a TBI and screened negative for hazardous drinking on the AUDIT at the time of testing. The second classification included adolescents with *former TBI* (experienced sometimes during their lifetime but not in past 12 months) and were not hazardous drinkers. Members in the third classification included adolescents with *recent TBI* (experienced in the past 12 months) and were not hazardous drinker. The fourth classification included adolescents who screened positive on the AUDIT at the time of testing (hazardous drinkers) but did not report TBI (*no former or recent*). The fifth classification included current hazardous drinkers with co-occurring *former TBI*, and the six classification included hazardous drinkers with co-occurring *recent TBI* (no *former TBI*). The second set of analyses (Table 5) were based on the following 3 levels classifications: adolescents who did not report a TBI (former or recent) nor did they screen positive on the AUDIT; adolescents who reported either former or recent TBI, or who screened positive on the AUDIT; and adolescents who screened positive on the AUDIT and also reported either former or recent TBI.

Analysis

Data derived from complex surveys using stratification and clustering fail the assumption of independent observations and thus underestimate variances (and in doing

they overstate significance levels resulting in false positive inferences). We therefore employed design-based estimation methods to accommodate such violations. Our subsample analyses utilized a complex sample design with 20 strata (region by school level), and 198 primary sampling units (high schools). The variance of our analyses was estimated by Taylor Series Linearization (TSL) executed in the Complex Sample module in SPSS version 23.0 (SPSS Inc., 2015). In addition to strata and clusters, our analyses employed case weights that factored inclusion probabilities, nonresponse and post stratification adjustments. We applied multinomial logistic regressions to assess the association between TBI-AUDIT classes with the 8 mental health, and 15 conduct behaviors, with and without holding sex and grade constant, against $P < 0.05$ (two-tailed). The results are based on 'valid' responses (n's); missing data (i.e. 'don't know' responses and refusals) were excluded. Listwise deletion reduced the estimation sample from 3264 to 3130.

Results

An estimated 11.8% (95% CI: 10.1, 13.8) of Ontario adolescents reported *former TBI*, 4.0% (95% CI: 2.9, 5.5) reported recent TBI, 13.7% (95% CI: 12.3, 15.3) were identified as hazardous drinkers, 4.1% (95% CI: 2.9, 5.8) reported *former TBI* with co-occurring hazardous drinking, 2.2% (95% CI: 1.6, 3.0) reported *recent TBI* with co-occurring hazardous drinking, and 64.1% (95% CI: 60.9, 67.2) were individuals who never had a TBI and scored negative on the AUDIT.

Demographic characteristics

Table 2 presents the demographic characteristics of the sample by TBI-AUDIT classifications. Odds ratios were similar for males versus females on all 6 TBI-AUDIT

classifications, while grade level in high-school significantly predicted TBI-AUDIT classification. Among adolescents in grade 12, odds ratios were 6 times significantly higher for hazardous drinking, nearly 12 times higher for reporting *former TBI* with co-occurring hazardous drinking, and 3 times higher for reporting *recent TBI* with co-occurring hazardous drinking, compared to baseline classification (neither conditions). Adolescents in grade 11 had odds nearly 4 times higher for hazardous drinking, and nearly 8 times higher for reporting *former TBI* with co-occurring hazardous drinking, compared to baseline classification. Among students in grade 10 the odds were 3 times higher for reporting *former TBI* with co-occurring hazardous drinking, compared to baseline classification.

Associations between TBI, problem drinking and recent Mental Health problems

Table 3 shows the results of multinomial regression analyses fitting TBI-AUDIT classification by mental health conditions. For 5 of the 8 mental health conditions, adjusted odds ratios associated with screening positive for hazardous drinking, without co-occurring history of TBI, were statistically significant, compared to individuals in the baseline classification (neither conditions) and ranged from 1.40 to 6.45. For 6 of the 8 mental health conditions assessed, adjusted odds ratios associated with *former TBI*, without co-occurring hazardous drinking, were statistically significant and ranged from 1.61 to 4.81. Only one of the 8 mental health conditions assessed had significant adjusted odds ratios associated with *recent TBI*. Adjusted odds were 9.14 times higher for suicide attempt among adolescents with *recent TBI* compared to those with no history of TBI that screened negative for hazardous drinking.

With the addition of hazardous drinking to *former TBI*, the adjusted odds ratios associated with 7 of 8 mental health conditions assessed increased, compared to either classification alone, and were statistically significant ranging from 3.75 to 9.70. With the addition of hazardous drinking to *recent TBI*, the adjusted odds-ratios associated with 7 of the 8 mental health conditions assessed increased, compared to either classification alone, and were statistically significant, ranging from 2.36 to 31.23. Self rated general health was not statistically significantly associated with any of the TBI-AUDIT classifications.

Associations between TBI, problem drinking and recent conduct behavioral issues

Table 4 shows the results of multinomial regression predicting membership in the 6 TBI-AUDIT classifications by 15 conduct behaviors. For 5 of 12 perpetrator behaviors, statistically significant adjusted odds ratios were associated with *former TBI* compared to the baseline classification (neither conditions). With the addition of hazardous drinking to *former TBI*, the adjusted odds-ratios associated with perpetrator reports of conduct behavior were higher and statistically significant on all 12 measures and ranged between 5.24 and 29.71. For all of the conduct behaviors in which the adolescent reported being a victim, adjusted odds ratios associated with *former TBI*, without hazardous drinking, were statistically significant and ranged between 1.56 and 2.61. With the addition of hazardous drinking to *former TBI*, compared to the baseline classification, the adjusted odds-ratios associated with all 3 conduct behavior victimization variables were statistically significant and ranged between 3.17 and 7.97.

For 9 of the 12 perpetrator type conduct behaviors assessed, statistically significant adjusted odds ratios associated with *recent TBI* classification were observed.

For all 3 victimization conduct behaviors associated with *recent TBI* adjusted odds ratios were significant. With the addition of current hazardous drinking to recent TBI, the adjusted odds-ratios associated with perpetrator reports of conduct behavior were statistically significant on 10 of the 13 measures compared to individuals in the baseline membership class (neither conditions). With the addition of hazardous drinking to recent TBI, compared to the baseline classification , the adjusted odds-ratios associated with all 3 measures of conduct behavior victimization were statistically significant. The adjusted odd ratios of perpetration of conduct behaviors associated with hazardous drinking was statistically significant for all of the 12 measures.

Comparing the individual versus combined effects of TBI and problem drinking

Table 5 summarizes analyses designed to highlight the incremental impact of experiencing co-occurring TBI and hazardous drinking compared to either condition by itself (referent). The analysis also included those with no history of TBI or hazardous drinking. Comparisons between the three groups revealed significantly higher adjusted odds ratios that ranged between 2.17 to 2.98 on all 6 mental health measures for students who experienced both conditions in comparison to those who experienced one. Students who reported both conditions (TBI and co-occurring hazardous drinking) had significantly higher adjusted odds of mental health problem indicators on measures of psychological distress, use of medication for depression or anxiety, contemplating suicide in the past 12 months, attempting suicide in the past 12 months, and fair or poor self-reported mental health. The two groups did not differ on three mental health measures (called a crisis or help line, used prescribed medication for ADHD, reporting fair or poor general health). Compared to students who experienced one condition (had

history of TBI or screened positive for hazardous drinking), students reporting neither had significantly lower adjusted odds of mental health problem indicators on seven of the eight measures. The only exception was that the groups did not differ on self-reported general health.

For measures of perpetration (Table 5), students who reported co-occurring TBI and hazardous drinking had significantly higher adjusted odds of reporting taking a car without permission, damaging property, selling cannabis, stealing more than $50, beating up or hurting someone, breaking into a locked building, carrying a weapon, setting a fire, fighting on school property, and bullying others at school. The two groups did not differ on the adjusted odds of taking things worth less than $50 and running away from home. Compared to the group reporting one condition (TBI or hazardous drinking), those reporting neither had significantly lower adjusted odds on all measures of perpetration. For measures of victimization, those reporting both conditions (TBI and co-occurring hazardous drinking) had significantly higher adjusted odds of being threatened with a weapon and being bullied on the internet, but did not differ on odds of being bullied at school. Those reporting neither conditions (never had TBI and failed to score positive for hazardous drinking), compared to the group reporting one of the two conditions (TBI or hazardous drinking), had significantly lower adjusted odds on all three measures of victimization.

Discussion

In this population of Ontario high school students, one in eight reported *former TBI* (incurred during lifetime but not in the past 12 months) and were not current

drinkers; one in 25 were identified as hazardous drinkers with co-occurring recent TBI; one in 7 were identified as hazardous drinkers and had no history of TBI; one in 24 were identified as hazardous drinkers with co-occurring history of former TBI; and one in 45 were identified as hazardous drinkers with co-occurring recent TBI. In our sample, group membership did not vary by sex, but did vary by age, as measured by school grade. Significant odds ratios emerged for hazardous drinking with co-occurring history of former TBI among grade 10, 11 and 12 students compared to those in grade 9. Odds ratios were three times higher for hazardous drinking with co-occurring recent TBI among grade 12 compared to grade 9 students. Odds ratios were 3.5 and 6 times higher for hazardous drinking among grade 11 and 12 students, respectively, compared to grade 9 students. These differences mirror patterns of such differences in the adolescent population reported previously.[4,18-21,33,36] These results show the emergence of hazardous drinking over the high school years, and suggest that this emergence may occur at an elevated rate among those with former and current TBI.

Since we were unable to find previous studies examining the co-occurrence of hazardous drinking and TBI in a representative sample of adolescents, there is no study to compare our estimates. However, adult studies have shown that among individuals currently in rehabilitation for substance abuse the rates of co-occurring alcohol problems with history of TBI ranged between 38% to 63%.[37-38] We found that of all students screening positive at the time of testing for hazardous drinking, 32.4% also reported a history of TBI, which approaches the range observed in these adult studies, and confirms the notable existence of the TBI-alcohol co-occurrence.[37-38] Co-occurring recent TBIs with hazardous drinking were associated with higher odd-ratios, overall, for mental health issues, while former TBIs with hazardous drinking were associated with higher odd-ratios, overall, for conduct behavior compared to no TBI and no hazardous drinking reference category, than the other TBI and hazardous drinking

classifications examined. Below we discuss each in turn.

Associations between TBI, problem drinking and current mental health issues

The results we report here replicate and extend previous results on the individual impact of hazardous drinking and TBI on mental health indicators.[19-20] Odd ratios among current hazardous drinkers were significantly higher for elevated psychological distress, being prescribed medication for anxiety, depression or both, being prescribed medication for ADHD, suicidal ideation, suicide attempt, and self-rated fair or poor mental health in the past 12 months. Previous research has shown that depression, anxiety, ADHD, or combinations of these conditions are risk factors for hazardous drinking among adolescents because some youth use drinking as a coping strategy for dealing with internal distress.[39-41] Evidence also shows that adolescents diagnosed with mental disorders including anxiety, depression and ADHD have significantly elevated rates of alcohol problems.[42-43]

Adjusted odds ratios were significantly higher among adolescents who reported *former TBI* (*but not recent TBI*) for being prescribed medication for anxiety, depression or both, being prescribed medication for ADHD, suicidal ideation, suicide attempt, reporting fair or poor mental health, and calling a crisis line for help compared to adolescents who never had a TBI and were not problem drinkers. These results replicate findings linking these mental health issues to long term history of TBI.[44-45] *Recent TBI* without hazardous drinking did not increase the odds of the mental health issues assessed here, with the exception of suicide attempts. Specifically, adolescents who reported *recent TBI* had 9 times higher adjusted odds of reported attempted suicide in the past 12 months, than those who never had a TBI and were not identified as

hazardous drinkers. Suicide is the third leading cause of death among people aged 14 to 25 years old, and has recently been identified as a condition that is linked with both TBI and hazardous drinking.[25,46-47] A recent systematic review of studies published between 2007-2012 revealed that the link between suicidal ideation and TBI was robust,[48] while a Canadian study of 235,000 adults found that adults with a history of concussions were three times more likely to die by suicide compared to individuals who never had a concussion.[46] Our results confirm that each category of *former TBI, recent TBI,* or hazardous drinking are strongly related to suicidal ideation and suicide attempt in adolescents. Most importantly, data here show that this link is intensified among adolescents experiencing both conditions. Specifically, compared to the rest of the TBI-hazardous drinking classifications we examined, the largest odds-ratios of suicide attempts were observed among adolescents who were both *hazardous drinkers and had recent TBI* than adolescents who never had a TBI, nor were problem drinkers. Therefore, it is important to be aware of the risk of suicide ideation and attempt associated with excessive alcohol use among youth who recently had a TBI, as well as the attitudes that these messages engender in adolescents with regards to self-inflicted harm. Overall these results point to the urgent need for combined prevention efforts in school for TBI, alcohol use, and suicide.

Hazardous drinkers with *recent TBI* had more and higher odd ratios for most current mental health behaviors than hazardous drinkers with *former TBI*. To our knowledge this is the first time when temporarily interpretable patterns of association such as these have been demonstrated in a population based study. However, given the correlational nature of our design we cannot draw causal inferences. It is therefore

unclear whether mental health issues, such as the ones examined here, represent immediate consequences of recent TBI that co-occur with problem drinking which, with the passage of time, may decrease in their odd ratios due to their identification and treatment (e.g., prescribed medication, counselling, etc.), or risks for the TBI problem drinking co-occurrence. Previous research evidence suggests that the increase in mental health issues in the first year post TBI with problem drinking is not uncommon. For example, depression is about 8 times more common after TBI in the first year post-injury when co-occurring with increased alcohol consumption, among adults.[49] Alcohol post TBI, short and long term, can interfere with prescribed medication leading to overdose, multiplying effects (alcohol plus other medication effects), or death.[49-50] Furthermore, it is important to recognize that adolescents who consume alcohol are also more likely to use other substances and vice versa, particularly among TBI survivors.[4,20] Given that many adolescents are involved not only with alcohol but also with other substances and may have a mental disorder and TBI, interventions should be designed to address these complexities. Taken together, these results demonstrate that whether the TBI occurred recently (past year) or previously (more than a year ago) including its occurrence and considering its contribution in the management of mental health conditions and rehabilitation efforts may be an important consideration for clinicians.

Associations between TBI, problem drinking and current conduct behaviours

Adolescents who classified as *hazardous drinkers with former TBI* had numerous and higher odds ratios for conduct behaviours than *hazardous drinkers with recent TBI*. These results may suggest that the odds ratios of behavioural issues long term increases rather than subside, as one may expect. On the other hand, these results

are not surprising if TBI is accompanied by other comorbid conditions (e.g. hazardous drinking, mental health issues, etc.). On the other hand, some researchers found that conduct problems related to TBI often do not appear until several months or years following an injury unless the TBI is more severe.[51-52] TBI sustained during youth can lead to sustained and persistent impaired functioning in many areas, including neurologic, neuromuscular, neurocognitive, and neuropsychiatric.[51] The extent of these deficits is not fully understood or evident immediately after the injury. Post injury problems with impulsivity, difficulty paying attention and focused attention, and restlessness post TBI is common in about one third of youth.[53] Older children and adolescents have more problems inhibiting behavior that may be expressed through impatience, irritability, aggression and inappropriate comments[54] and may act on an impulse that could have been ignored before the injury. With the addition of alcohol use and other comorbidities behavioral issues, violence and aggression are not uncommon.[25,55]

A social ecological perspective suggests that several social contexts and the interdependencies of these contexts contribute to the development of adolescent hazardous drinking, risk behaviors leading to TBI, and alcohol misuse post TBI.[56-62] While adolescent problem drinking and TBI, especially sports injuries, have been recognized to be shaped by the socialization contexts and processes,[61] research on schools and neighborhoods is far less common than research on family and peer influences.[63] Yet they both contribute and perpetuate the socialization of co-occurring hazardous drinking and TBI.[59,63] For example, aggressive play (seeking revenge on ice) in minor league hockey is often reinforced by the player's social environment and

justified by players as a demonstration of loyalty to teammates and especially injured teammates.[56,59] The social context is particularly relevant to the population examined here since the main mechanism of injury for recent TBIs among Ontario adolescents since 2011 has remained sports injuries, particularly team sports (e.g., hockey, soccer, etc.).[19,59] Overemphasis on winning in hockey games, group membership dynamics, coaches' motivation to further their own opportunities in the sport, or parents' financial interest and vocational prospects for their child's future are few of the factors that have been shown to contribute to lack of management post TBI in youth hockey by underreporting head injuries.[59] While much of human behaviour is influenced by our genetic makeup, the socialization process can mold it in particular directions by encouraging specific beliefs and attitudes as well as selectively providing experiences.[58,61-63] The implication of the results we report here are important for prevention and monitoring, long term given the mental health and behavioural TBI aftermath consequences we observed. It may be useful for teachers, sports coaches, and school guidance councilors to be made aware of students who have a history of TBI, and to maintain on-going communication with parents to prevent the development of harmful co-morbid conditions overtime.[58] Prevention efforts may want to consider forming a means of facilitating parents, sports coaches, clinicians and school guidance councilors to work together as a team to provide support for the adolescent short and long term who may be facing disruption of brain-pathways dedicated to self-management, leading to conduct and behavioral issues. The results of our study warrant the need for a greater understanding of the ways in which sports and alcohol misuse socialization combine to create, externally, a culture of violence and aggression, and

internally, mental health issues. Physicians, health professionals, researchers, and concerned parents for their part, can help advocate for interventions that involve all levels of social context and processes (e.g., home, school, community); serve as role models for a healthy approach to sport and peer interactions and socialization; counsel players, parents and coaches, and school guidance councillors, and raise awareness about safe play and the risks associated with certain practices in sports.

This is the first population-based study to compare the individual impact of current hazardous drinking and history of TBI with their combined effects on mental health and conduct behaviors outcomes. The results provide strong support for the suggestion that the negative effects of the co-occurrence of hazardous drinking with TBI may be synergistic. When hazardous drinking co-occurred with either *former or recent* TBI, the odds were significantly elevated for nearly all the mental health and perpetrator related violent and non-violent conduct behaviors, as well as reports of being the victim of being threatened with a weapon on school property or being bullied at school or via the internet, compared to reporting only TBI or hazardous drinking. The incremental impact of the co-occurrence of hazardous drinking and TBI has not previously been demonstrated, but it appears substantial.

Limitations

At the same time, readers should be mindful of our study's limitations. First, the results are based on self-report and thus subject to bias that may affect validity. Second, the data are obtained from a cross-sectional survey and thus do not allow causal conclusions to be drawn. While our post-survey assessment of substance use and mental health indicators did not show evidence of appreciable bias, the survey's student

response rate (63%), while considered normative for such studies, may be subject to nonresponse bias.[4] Although most clinical literature has investigated the relationship between TBI and mental health symptoms post TBI, alcohol misuse and mental health problems may also be linked to risk-taking behaviors that precipitate TBI. Finally, our operational definition of TBI excluded milder forms of the injury that leaves the individual confused or dazed without loss of consciousness, or with a loss of consciousness for less than 5 minutes. Future studies should consider evaluating the role of date of first injury and level of TBI severity in the associations we reported here, which we did not asses.

Conclusion

Nevertheless, these results are of substantial interest. First, the results not only replicate but extend findings that the joint occurrence of hazardous drinking and TBI among adolescents is associated with significant adverse mental health and conduct behavior correlates. The incremental negative consequences of the co-occurrence of hazardous drinking and TBI in an adolescent population we report is novel. Additionally, whether the TBI occurred in the past year or previously may be an important consideration. Separation of *recent* from *former TBI* strengthens the ability to make causal interpretations. The TBI-AUDIT classifications are temporally interpretable (e.g., past history of TBI versus current hazardous drinking assessment). This study contributes to the slowly developing international population studies assessing alcohol misuse and TBI.

Our results suggest that, when dealing with adolescents with a drinking problem, it may be important to look for history of TBI, and conversely, when dealing with

adolescents with TBI, it may also be important to look for evidence of hazardous drinking, as co-occurrence appears to be associated with substantially greater mental health problems and conduct behaviours. Additional research to understand the incremental problems experienced by those with co-occurring hazardous drinking and TBI, and to understand the causal relationships involved, is greatly needed. Such examinations are crucial in helping guide clinicians, physicians, prevention and rehabilitation programs.

Author contributions: Drs. Ilie and Mann had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analyses.

Study concept and design: Ilie, Mann, Boak, Hamilton, Rehm, Cusimano

Acquisition of data: Mann, Hamilton, Boak

Analysis and interpretation of data: Ilie, Mann, Boak, Adlaf

Drafting of the manuscript: Ilie

Critical revision of the manuscript for important intellectual content: Ilie, Mann, Boak, Hamilton, Rehm, Cusimano

Statistical analysis: Ilie, Mann

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Data availability:

No additional data available.

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Table 1. Covariates and predictors included in the analysis

Variable	*Definition*
Sex – covariate	Male, female
Grade – covariate	Four categories: 9th, 10th, 11th, 12th
Mental health measures	
Psychological distress	Moderate to high vs. low psychological distress in the past 4 weeks GHQ[25]
Used prescribed medication to reduce anxiety, depression, or both	Past 12 months taking prescribed medication for anxiety, depression or both (yes=1, 0 otherwise)
Suicidal ideation	Seriously considered suicide in the past 12 months (yes= 1, 0 otherwise)
Suicide attempt	Attempted to commit suicide in the past 12 months (yes=1, 0 otherwise)
Called a crisis or help line in past 12 months	Called a youth crisis or help line in past 12 months for help (yes= 1; 0 otherwise)
Used prescribed medication to treat ADHD	Past 12 month use of prescribed medication to treat ADHD (yes=1, 0 otherwise)
Self-rated mental health status	Reported excellent/ good mental health vs. fair or poor mental health (yes=1; 0 otherwise)
Self-rated health status	Reporting excellent/ good health vs. fair or poor health in general (yes=1; 0 otherwise)
Violent and non-violent conduct behaviors (perpetrator or victim)	
Drove a car without the owner's permission	Taken the car for a ride without the owner's permission at least once in the past 12 month (yes=1; 0 otherwise)

Damage to property	Damaged something on purpose that did not belong to you at least one in past 12 months (yes=1; 0 otherwise)
Sold marijuana or hashish at school	Sold marijuana or hashish at least once in the past 12 months (yes=1; 0 otherwise)
Stealing (things worth 50$ or less)	Taken things worth $50 or less at least once in the past 12 months (yes=1; 0 otherwise)
Stealing (things worth more than 50$)	Taken things worth $50 or more at least once in the past 12 months (yes=1; 0 otherwise)
Physical violence (in purpose)	Beat up, hurt anyone in purpose at least once in the past 12 months (yes=1; 0 otherwise)
Physical violence at school	Engaged in a physical fight on school property at least once in past 12 months (yes=1; 0 otherwise)
Breaking into property	Times broken into a locked building other than one's own at least once in the past 12 months (yes=1; 0 otherwise)
Possession of a weapon (e.g., gun, knife) on school property	Carried a weapon such as a gun or a knife at least once in the past 12 months (yes=1; 0 otherwise)
Running from home	Ran away from home in the past 12 months (yes=1; 0 otherwise)
Set fire	Set something on fire you weren't supposed to at least once in the past 12 months (yes=1; 0 otherwise)
Bullied others	Bullied others at school at least once in the past 12 months (yes=1; 0 otherwise)
Being threatened with a gun or weapon at school (*Victim*)	Was threatened with a gun or a weapon on school property in the past 12 months (yes=1; 0 otherwise)
Being bullied at school (*Victim*)	Been bullied at school at least once in the past 12 months

	(yes=1; 0 otherwise)
Being bullied through the internet (*Victim*)	Been bullied through the internet once in the past 12 months (yes=1; 0 otherwise)

Table 2. Descriptive analyses predicting membership classification: TBI former (lifetime but not past 12 months; no current hazardous drinking); TBI recent (past 12 months; no current hazardous drinking), Hazardous Drinking (never had TBI), former TBI with co-occurring Hazardous Drinking (no recent TBI), recent TBI recent with co-occurring Hazardous Drinking, and base category (no TBI or Hazardous Drinking) by demographics, among adolescents grades 9 through 12, Ontario, Canada, 2013, n=3130

	Base category % (95% CI) OR (95% CI) n=2082	Former TBI (no Hazardous Drinking) % (95% CI) OR (95% CI) n=367	Recent TBI (no Hazardous Drinking) % (95% CI) OR (95% CI) n=104	Hazardous Drinking (no TBI) % (95% CI) OR (95% CI) n=390	Former TBI & Hazardous Drinking % (95% CI) OR (95% CI) n=117	Recent TBI & Hazardous Drinking % (95% CI) OR (95% CI) n=70
Sex	F (5, 94) = 1.08					
Male	62.0 (57.4,66.5) 1.00 (Ref) n=864	12.6 (10.0,15.8) 1.23 (.85,1.78) n=187	4.4 (3.0,6.6) 1.31 (.67, 2.53) n=51	13.5 (11.6,15.7) 1.03 (.78,1.37) n=155	5.1 (3.1,8.4) 1.79 (.93,3.44) n=60	2.3 (1.4,3.8) 1.16 (.57,2.32) n=34
Female (Ref.)	66.3 (62.5,69.8) n=1218	11.0 (8.8,13.6) n=180	3.6 (2.2,6.0) n=53	13.9 (11.7, 16.6) n=235	3.1 (2.1, 4.4) n=57	2.1 (1.4, 3.1) n=36
Grade	F (15, 84)=14.37***					
12	72.1 (68.6,75.3) 1.00 (Ref.) n=458	14.8 (11.8,18.4) .84 (.52, 1.34) n=60	6.5 (4.4,9.5) .84 (.39, 1.79) n=22	4.8 (3.2,7.1) 6.35(4.16,9.69)*** n=162	0.8 (0.3,1.9) 11.75(4.03,34.27)*** n=46	1.1 (0.5,2.5) 3.07(1.16,8.15)** n=24
11	71.1 (65.9,75.7) 1.00 (Ref.) n=518	13.3 (10.0,17.4) .85 (.55, 1.30) n=88	2.4 (1.2,4.8) .58 (.32, 1.04) n=22	8.0 (4.9,12.8) 3.58(1.98,6.46)*** n=125	2.5 (1.3, 4.9) 7.88(2.96,20.95)*** n=35	2.8 (1.4,5.5) 2.47(.74,8.24) n=21
10	63.2 (57.4,68.6) 1.00 (Ref.) n=548	11.0 (8.2,14.5) .91 (.65, 1.28) n=110	3.3 (1.9,5.7) .37 (.18, .78) n=24	15 (11.1,19.9) 1.69 (.87,3.39) n=63	5.3 (3.7,7.4) 3.37(1.06,10.76)* n=22	2.4 (1.0,5.6) 2.57(.84,7.89) n=14
9 (Ref.)	54.4 (48.9,59.7) n=558	9.4 (6.9,12.6) n=109	4.1 (2.2,7.6) n=36	22.9 (19.6,26.5) n=40	6.7 (4.2,10.7) n=14	2.5 (1.6,3.8) n=11

Table 3. Multinomial Logistic Regression analyses predicting membership classifications: *Former TBI* (lifetime but not past 12 months; no current hazardous drinking); *Recent TBI* (past 12 months; no current hazardous drinking), *Hazardous Drinking (never had TBI)*, *Former TBI with co-occurring Hazardous Drinking* (no recent TBI), *Recent TBI recent with co-occurring Hazardous Drinking*, and *Base Category* (Ref.; no TBI or Hazardous Drinking) by mental health measures among adolescents grades 9 through 12, Ontario, Canada, 2013, n=3130

	Former TBI (n=367) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Recent TBI (n=104) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Hazardous Drinking (n=390) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Former TBI & Hazardous Drinking (n=117) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Recent TBI & Hazardous Drinking (n=70) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)
Moderate to high levels of psychological distress					
F (5,94) = 7.29***	1.17 (.80, 1.73)	1.15 (.54, 2.43)	1.49 (1.17, 1.90)**	3.10 (1.67, 5.75)***	2.14 (1.07, 4.30)*
F (15,84) = 9.80***	1.25 (.87, 1.81)	1.24 (.64, 2.40)	1.65 (1.29, 2.13)***	4.06 (2.21, 7.44)***	2.36 (1.11, 5.02)*
Past 12 months prescription medication for anxiety, depression or both					
F (5,94) = 6.36***	2.26(1.08,4.73)*	1.90 (.65, 5.55)	2.11 (1.13, 3.96)*	6.15 (2.75, 13.77)***	6.24 (2.73, 14.28)***
F (15,84) =11.80***	2.44 (1.18, .07)*	2.08 (.73, 5.86)	1.74 (.81, 3.73)	6.02 (2.59, 13.0)***	6.17 (2.64, 14.42)***
Past 12 months did you contemplate attempt suicide					
F (5,90) = 7.49***	1.65 (1.12,2.45)*	1.98 (.88, 4.49)	1.88 (1.31, 2.70)**	2.71 (1.29, 5.69)**	4.45 (1.90, 10.42)**
F (15,80) =11.80***	1.74(1.17,2.57)**	2.11 (.99, 4.47)	2.17 (1.50, 3.13)***	3.48 (1.62, 7.48)**	4.96 (2.07, 11.90) ***
Past 12 months did you actually					

attempt suicide F (5,90) = 15.93*** F (15,80) =14.29***	4.43(2.27,8.64)*** 4.81(2.48,9.35)***	8.14(2.68,24.73)*** 9.14(3.22,25.93)***	5.03 (2.64, 9.58)*** 6.45 (3.09, 13.48)***	6.36 (2.11, 19.14)** 9.70 (3.37, 27.96)***	24.77(9.10, 67.42)*** 31.23(10.29,94.82)***
Called a child crisis or help line in past 12 months F (5, 94) = 5.34*** F (15, 84)=9.77***	2.05(1.49, 6.26)** 3.26(1.58, 6.74)**	.32 (.08, 1.23) .34 (.09, 1.34)	2.12 (1.01, 4.43)* 2.11 (.99, 4.46)	3.20 (1.05, 9.70)* 3.75 (1.24, 11.33)*	5.49 (2.0, 15.08)** 5.80 (2.13, 15.80)**
Past 12 months used prescribed medication to treat ADHD F (5, 94) = 4.10** F(15,84)=11.32***	2.99 (1.32,6.79)** 2.88 (1.25, 6.59)*	5.39 (.97, 30.05) 5.12 (.93, 28.14)	2.86 (1.45, 5.62)** 2.99 (1.47, 6.06)**	5.23 (1.90, 14.37)** 5.00 (1.74, 14.41)**	7.29 (1.83, 29.01)** 7.33 (1.90, 28.30)**
Reporting fair or poor mental health in general F (5, 94) = 5.18*** F (15, 84) =8.79***	1.53 (1.03, 2.28)* 1.61 (1.10, 2.36)*	1.30 (.58, 2.87) 1.38 (.68, 2.80)	1.31 (.98, 1.77) 1.40 (1.02, 1.91)*	3.37 (1.71, 6.64)** 3.93 (2.03, 7.61)***	2.85 (1.42, 5.74)** 3.07 (1.46, 6.44)**
Reporting fair or poor health in general F(5, 94) = .20 F(15, 84)=10.83***	.98 (.59, 1.64) .99 (.59, 1.66)	1.10 (.38, 3.17) 1.11 (.39, 3.18)	1.15 (.63, 2.10) 1.12 (.62, 2.04)	1.40 (.61, 3.20) 1.40 (.63, 3.12)	1.25 (.33, 4.65) 1.23 (.34, 4.48)

Notes: F - design adjusted Wald F tests; Odds Ratios (OR) and Adjusted Odds Ratios (AOR) were calculated using logistic regression. AORs were evaluated while holding fixed values of the complexity of the design, sex and grade; *** P < 0.001; ** P < 0.01; * P<0.05

Table 4. Multinomial Logistic Regression analyses predicting membership classifications: *Former TBI* (lifetime but not past 12 months; no current hazardous drinking); *Recent TBI* (past 12 months; no current hazardous drinking), *Hazardous Drinking (never had TBI)*, *Former TBI with co-occurring Hazardous Drinking* (no recent TBI), *Recent TBI recent with co-occurring Hazardous Drinking*, and *Base Category* (Ref.; no TBI or Hazardous Drinking) by conduct behaviours among adolescents grades 9 through 12, Ontario, Canada, 2013, n=3130.

	Former TBI (n=367) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Recent TBI (n=104) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Hazardous Drinking (n=390) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Former TBI & Hazardous Drinking (n=117) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)	Recent TBI & Hazardous Drinking (n=70) vs. Base Category (n=2082) OR (95% CI) AOR (95% CI)
Taken the car for a ride without the owner's permission					
F (5,94)=26.32***	2.14 (.95, 4.82)	4.29 (1.35, 13.65)*	6.48(4.02,10.43)***	17.92 (9.57, 33.55)***	3.17 (.97,10.39)
F (15,84)=14.52***	2.17 (.97, 4.88)	4.27 (1.33, 13.69)*	5.61 (3.53, 8.94)***	15.15 (7.77, 29.56)***	2.93 (.87, 9.93)
Damaged something on purpose					
F (5,94)=14.57***	1.46 (.89, 2.38)	6.21(2.76,13.98)***	2.72 (1.65, 4.49)***	5.50 (2.50, 12.07)***	9.29(4.44,19.44)***
F (15,84)=21.56***	1.42 (.87, 2.33)	6.13 (2.67, 14.06)***	3.14 (1.86, 5.29)***	6.16 (2.65, 14.31)***	9.98 (4.65, 21.44)***
Sold marijuana or hashish					
F (5.94)=31.48***	2.51 (1.26, 5.02)*	10.16 (3.22,32.06)***	12.11 (6.86,21.36)***	29.29 (16.63,51.58)***	8.82 (3.25, 23.97)***
F(15,84)=18.00***	2.41 (1.74, 4.95)*	9.80(3.21,29.94)***	13.35 (6.37,27.98)***	29.71 (14.88,59.31)***	9.02 (2.86, 28.45)***
Taken things worth $50 or less					
F (5,94)=19.02***	2.07 (1.31, 3.25)**	2.18 (1.06, 4.45)*	5.17 (3.18, 8.39)***	6.92 (4.02, 11.91)***	2.59 (.78, 8.54)
F (5,84)=20.06***	2.04 (1.30, 3.22)**	2.12 (1.02, 4.12)*	5.31 (3.43, 8.22)***	6.69 (3.86, 11.59)***	2.57 (.78, 8.49)
Stealing more than $50					
F (5,94)=11.28***	1.62 (.59, 4.47)	2.83 (.86, 9.33)	7.77 (3.39, 17.82)***	15.17 (5.93, 38.84)***	8.13 (2.41, 27/36)**

F (15,84)=13.97***	1.62 (.58, 4.54)	2.75 (.83, 9.12)	7.05 (2.96, 16.81)***	12.88 (4.70, 35.30)***	7.61 (2.24, 25.87)**
Beat up, hurt anyone in purpose					
F (5,94)=18.08***	2.40 (1.22, 4.75)*	4.34 (1.84, 10.20)**	4.97 (2.71, 9.10)***	9.61 (4.93, 18.73)***	8.64 (2.98, 25.04)***
F (15,84)=17.64***	2.31 (1.15, 4.64)*	4.18 (1.77, 9.84)**	5.98 (3.16, 11.32)***	11.06 (5.26, 23.24)***	9.40 (3.19,27.66)***
Broken into a locked building other than one's own					
F (5,94)=20.49***	.48 (.18, 1.30)	1.92 (.59, 6.26)	4.81 (2.31, 10.05)***	8.70 (3.83, 19.78)***	9.43 (2.84, 31.34)***
F (15,84)=10.72***	.48 (.18, 1.26)	1.85 (2.08, 6.46)	4.79 (2.08, 11.05)***	8.01 (3.12, 20.62)***	9.26 (2.59, 33.13)***
Carried a weapon such as a gun or a knife					
F (5,94)=13.767***	5.13 (2.81,9.35)***	6.66 (2.75, 16.10)***	5.67 (2.82, 11.38)***	9.99 (4.85, 20.57)***	9.21 (3.57, 23.74)***
F (15,84)=29.00***	4.92 (2.69,8.97)***	6.40 (2.35, 17.43)***	7.67 (3.95, 14.90)***	12.73 (5.79, 27.99)***	10.71(4.06,28.20)***
Run away from home					
F (5,94)=13.67***	1.76 (.99, 3.13)	3.67 (2.30, 5.84)***	4.16 (2.56, 6.77)***	4.85 (2.01, 11.73)**	4.49 (1.57, 12.86)**
F (15,84)=12.60***	1.78 (.99, 3.16)	3.78 (2.44, 5.86)***	4.55 (2.82, 7.33)***	5.79 (2.16, 15.52)**	4.74 (1.59, 14.17)**
Set fire					
F (5,94)=14.58***	1.47 (.94, 2.29)	3.04 (1.26, 7.35)*	4.00 (2.69, 5.92)***	6.07 (3.03, 12.16)***	3.54 (1.36, 9.20)*
F (15,84)=24.63***	1.40 (.92, 2.14)	2.96 (1.17, 7.46)*	5.34 (3.41, 8.37)***	7.88 (3.77, 16.47)***	4.02 (1.59, 10.15)**
In a physical fight on school property					
F (5,94)=6.65***	2.36 (1.42, 3.92)**	6.59 (2.77, 15.68)***	1.98 (.96, 4.11)	4.91 (2.26, 10.68)***	4.21 (1.55, 11.46)**
F (15,84)=15.92***	2.25 (1.38, 3.66)**	6.78 (2.70, 17.01)***	2.50 (1.14, 5.49)*	5.62 (2.28, 13.83)***	4.77 (1.77, 12.86)**
Bullied others at school					
F (5,94)=10.05***	1.52 (1.00, 2.32)	1.56 (.54, 4.50)	2.12 (1.40, 3.20)***	4.54 (2.62, 7.85)***	3.81 (1.85, 7.83)***
F (5,84)=14.74***	1.48 (.98, 2.25)	1.52 (.52, 4.49)	2.50 (1.61, 3.89)***	5.24 (2.93, 9.37)***	4.11 (2.05, 8.26)***
Was threatened with a gun or a weapon					

(VICTIM) F (5,94)=9.20*** F (5,84)=17.53***	2.72 (1.42, 5.24)** 2.61 (1.37, 4.95)**	7.35 (2.39, 22.60)** 7.12 (2.35, 21.55)**	2.48 (1.27, 5.29)* 2.90 (1.29, 6.52)*	7.19 (2.18, 16.25)*** 7.97 (3.25, 19.55)***	6.72 (2.64, 17.16)*** 7.20 (2.87, 18.08)***
Been bullied at school (VICTIM) F (5,94)=3.33** F (5,84)=9.41***	1.63 (1.15, 2.31)* 1.63 (1.16, 2.28)*	2.04 (1.06, 3.95)* 2.08 (1.12, 3.87)*	1.24 (.88, 1.74) 1.52 (1.08, 2.15)*	2.07 (1.00, 4.30) 2.77 (1.34, 5.71)**	2.44 (1.20, 4.95)* 2.77 (1.37, 5.57)**
Been bullied through the internet (VICTIM) F (5,94)=6.73*** F (5,84)=12.34***	1.55 (1.03, 2.34)* 1.56 (1.03, 2.38)*	3.22 (1.47, 7.10)** 3.36 (1.48, 7.64)**	1.48 (.99, 2.22) 1.76 (1.18, 2.64)**	3.29 (1.80, 6.02)*** 4.17 (2.18, 7.98)***	WHl2.64 (1.22, 5.70)* 2.94 (1.20, 6.64)*

Notes: F - design adjusted Wald F tests; Odds Ratios (OR) and Adjusted Odds Ratios (AOR) were calculated using logistic regression.

aORs were evaluated while holding fixed values of the complexity of the design, sex and grade; *** P < 0.001; ** P < 0.01; * P<0.05

Table 5. Multinomial Logistic Regression analyses predicting membership classifications by history of TBI and Hazardous Drinking: either History of TBI or Hazardous Drinking, separately; no History of TBI or Hazardous Drinking; co-occurring History of TBI with current Hazardous Drinking for mental health and conduct behaviors measures, n=3130

	No history of TBI or hazardous drinking (n=2082) vs. History of TBI or Hazardous Drinking (n=881) OR (95% CI) AOR (95% CI)	History of TBI with hazardous drinking (n=187) vs. History of TBI or Hazardous Drinking (n=881) OR (95% CI) AOR (95% CI)
Mental health measures		
Moderate to high levels vs. low levels of psychological distress		
F (2,352) = 24.11***	.68 (.55, .85)***	2.26 (1.51,3.39)***
F (2,355) = 24.27***	.66 (.53, .82)***	2.42 (1.16, 3.63)***
Past 12 months prescription medication for anxiety, depression or both		
F (2,181) = 6.36***	.46 (.26,.84)***	2.89 (1.63,5.12)***
F (2,180) = 12.60***	.49 (.26, .92)***	2.98 (1.68, 5.29)***
Past 12 months did you contemplate attempt suicide		
F (2,339) = 17.82***	.57 (.44,.75)***	1.95 (1.19,3.17)*
F (2,333) = 19.99***	.53 (.40,.70)***	2.17 (1.21,3.58)***
Past 12 months did you actually attempt suicide		
F (2,327) = 25.34***	.26 (.17,.41)***	2.39 (1.21,4.72)***
F (2,306) = 28.17***	.23 (.15,.35)***	2.95 (1.39,6.26)***
Called a child crisis or help line in past 12 months		
F (2,355) = 10.98***	.34 (.28,.68)***	1.65 (.82,3.32)
F (2,349) = 12.32***	.40 (.26, .62)***	1.81 (.86,3.79)
Past 12 months used prescribed medication to treat ADHD		
F (2,346) = 12.11***	.32 (.18, .58)***	2.01 (.85, 4.72)
F (2,346) = 10.54***	.32 (.18,.57)***	2.04 (.82,5.05)
Reporting fair or poor mental health in general vs.		

excellent/ good mental health F (2,318) = 21.10*** F (2,312) = 22.03***	.63 (.51,.68)*** .61 (.50, .75)***	2.33 (1.42, 3.84)*** 2.44 (1.48,4.03)***
Reporting fair or poor health in general vs. excellent/ good health F(2,302) = .91 F (2,336) = .81	.80 (.51,1.24) .80 (.50,1.28)	1.15 (.55,2.38) 1.16 (.57, 2.34)
Conduct behaviours		
Taken the car for a ride without the owner's permission F (2,320)=46.22*** F (2,329)=31.17***	.21 (.13,.34)*** .26 (.16,.41)***	3.04 (1.95,4.76)*** 2.49 (1.54,4.03)***
Damaged something on purpose F (2,352)=33.68*** F (2,348)=32.07***	.42 (.30,.59)*** .41 (.29,.58)***	2.85 (1.75,4.65)*** 3.00 (1.78,5.08)***
Sold marijuana or hashish F (2,329)=43.92*** F(2,340)=34.01***	.14 (.08,.26)* .17 (.09,.30)*	3.11 (1.78,5.46)*** 2.76 (1.52,5.00)***
Taken things worth $50 or less F (2,355)=48.78*** F (2,350)=41.12***	.29 (.22,.39)*** .32 (.24,.42)***	1.76 (1.12,2.76)*** 1.59 (.99,2.54)
Stealing more than $50 F (2,356)=24.93*** F (2,356)=18.19***	.22 (.12,.42)*** .26 (.14,.49)***	3.20 (1.59,6.44)*** 2.71 (1.31,5.62)***
Beat up, hurt anyone in purpose F (2.253)=35.61*** F (2,253)=33.70***	.29 (.19,.433)*** .28 (.18,.42)***	2.54 (1.46,4.41)*** 2.76 (1.54,4.95)***
Broken into a locked building other than one's own F (2,355)=25.58*** F (2,355)=15.39***	.33 (.17,.64)*** .38 (.19,.75)***	4.41 (2.19,8.89)*** 1.85 (1.18,2.53)***
Carried a weapon such as a gun or a knife F (2,326)=32.61*** F (2,334)=33.92***	.21 (.12,.35)*** .20 (.12,.33)***	2.08 (1.16,3.74)*** 2.34 (1.23,4.44)***
Run away from home F (2,326)=22.81***	.33 (.24,.46)***	1.72 (.89,3.34)

F (2,307)=18,15***	.33 (.24,.47)***	1.75 (.84,3.66)
Set fire F (2,340)=22.86*** F (2,345)=27.65***	 .43 (.30,.62)*** .41 (.29,.58)***	 1.95 (1.22,3.10)*** 2.17 (1.35,3.49)***
In a physical fight on school property F (2,349)=18.53*** F (2,343)=25.03***	 .46 (.32,.65)*** .39 (.28, .54)***	 1.77 (1.07,2.94)* 2.11 (1.21,3.71)**
Bullied others at school F (2,354)=23.23** F (2,354)=26.61***	 .64 (.50,.82)*** .61 (.48,.79)***	 2.55 (1.63,3.97)*** 2.79 (1.77,4.39)***
Was threatened with a gun or a weapon (VICTIM) F (2,329)=16.37*** F (2,325)=18.27***	 .39 (.25, .61)*** .37 (.24,.57)***	 2.25 (1.06,4.77)* 2.45 (1.12,5.36)**
Been bullied at school (VICTIM) F (2,346)=7.97*** F (2,344)=16.93***	 .67 (.54,.84)*** .57 (.45,.71)***	 1.31 (.79,2.18) 1.65 (1.01,2.73)
Been bullied through the internet (VICTIM) F (2,354)=23.23** F (2,347)=18.66***	 .60 (.46,.78)*** .53 (.41,.69)***	 1.71 (1.02,2.88)* 1.99 (1.16,3.43)***

Notes: F - design adjusted Wald F tests; Odds Ratios (OR) and Adjusted Odds Ratios (AOR) were calculated using logistic regression. AORs were evaluated while holding fixed values of the complexity of the design, sex and grade; *** P < 0.001; ** P < 0.01; * P<0.05

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

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Provided-p2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Provided-p2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported Provided-p.5-6
Objectives	3	State specific objectives, including any pre-specified hypotheses Provided-p6
Methods		
Study design	4	Present key elements of study design early in the paper Presented-p.6-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection Provided in methods-p6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants Provided in methods-p6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable Provided in methods-p.7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group Provided in methodsp.8-9
Bias	9	Describe any efforts to address potential sources of bias Provided in discussion=p.16
Study size	10	Explain how the study size was arrived at Provided in methods-p.9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why Provided-p.7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding √-p9
		(*b*) Describe any methods used to examine subgroups and interactions √-p.12
		(*c*) Explain how missing data were addressed √p.9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy √p.8-9
		(*e*) Describe any sensitivity analyses - n/a
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed – Provided-p.9, also Tables 1-5 provide ns.,

		p.25-
		(b) Give reasons for non-participation at each stage – n/a
		(c) Consider use of a flow diagram – n/a
Descriptive data	14*	(a) Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders – Provided plus online link to supplementary methods of the sample-p.6-7
		(b) Indicate number of participants with missing data for each variable of interest – p.9, plus on-line link in methods p.7
Outcome data	15*	Report numbers of outcome events or summary measures – Provided-Table 1-p.25
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included – Provided- Tables 1-5, p25-37
		(*b*) Report category boundaries when continuous variables were categorized – n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period – n/a
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses – n/a
Discussion		
Key results	18	Summarise key results with reference to study objectives – Provided- p.3, p.13-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias – Provided-p.16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence – Provided-p.16
Generalisability	21	Discuss the generalisability (external validity) of the study results – Provided-p.16-17
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based – Provided-p.18

*Give information separately for exposed and unexposed groups.