Cycling-related crash risk and the role of cannabis and alcohol: a case-crossover study

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Abstract

Objective: To examine whether alcohol and cannabis consumption increase crash risk among non-fatally injured bicyclists (N=393) seen in three Canadian emergency departments, between April 2009 and July 2011.

Method: Employing a case-crossover design, cannabis and alcohol were identified through blood sample or by self-report. All cyclists were involved in a crash and exposure status (cannabis and alcohol) was compared between case period (current crash) and two control periods: prior to the last time the victim cycled around the same time of day; and the typical use prior to bicycling. Crash risk was assessed through conditional fixed effects logistic regression models.

Results: Approximately 15% of cyclists reported using cannabis just prior to the crash, and 14.5% reported using alcohol. Cannabis use identified by blood testing or self-report in the case period and by self-report in the control period yielded a crash risk of 2.38 (1.04-5.43); however, when self-report was used for both the case and control periods the estimate was 0.40 (0.12-1.27). Alcohol use, as measure either in blood or self-report, was associated with an odds ratio of 4.00 (95% CI: 1.64- 9.78); results were similar when alcohol was measured by self-report only.

Conclusion: Cannabis and alcohol use each appear to increase the risk of a non-fatal injury-related crash among bicyclists, and point to the need for improved efforts to deter substance use prior to cycling, with the help of regulation, increased education, and greater public awareness. However, cannabis results should be interpreted with caution, as the observed association with crash risk was contingent on how consumption was measured.

Introduction

Psychoactive substance use poses considerable risk to cyclists (Martinez-Ruiz et al., 2013). In particular, alcohol and cannabis impair the cognitive and psychomotor skills necessary for safe cycling behaviour (Crocker et al., 2010; Li et al., 2001). Alcohol has been detected in a high percentage of cyclists involved in crashes leading to injury or death (Crocker et al., 2010; Li et al., 2001; Li et al., 1996). Moreover, although evidence is limited, alcohol consumption among cyclists has been shown to increase the risk of an injury or fatal crash (Martinez-Ruiz et al., 2013; Li et al., 2001; Olkkonen and Honkanen, 1990) with a clear dose-response relationship starting at blood alcohol concentrations (BACs) of 0.02 g/dL, lower than the legal limit for driving a motor vehicle in most jurisdictions worldwide.

No studies have examined cannabis prevalence in cyclists involved in crashes, nor whether acute cannabis consumption increase bicycle crash risk. We know from data in Canada, the United States, and Europe that cannabis is the second most common substance, after alcohol, found in motor vehicle drivers injured or killed in crashes (Dussault et al., 2002; Mura et al., 2003). THC (Δ^9 tetrahydrocannabinol) is the main psychoactive component in cannabis which typically produces euphoria, relaxation, as well as changes in perception, deficits in attention span and memory, and psychomotor function (Hall and Degenhardt, 2009; Kalant, 2004). Experimental and simulator studies confirm that THC produces impairment in the skills necessary for safe driving, which include unsafe driving speed, poor lane control, and increased decision and response times (Berghaus et al., 1995).

There is also strong evidence that acute cannabis use increases motor vehicle crash risk (Bogstrand et al., 2012; Laumon et al., 2005; Ramaekers et al., 2004), including two recent meta-analysis that note a doubling in the risk of crashes leading to serious injury or death (Asbridge et al., 2012; Li et al., 2012). Using data from a case-crossover study of injured cyclists presenting to emergency departments after a crash, we assesses both the prevalence of alcohol and cannabis use in bicyclists involved in crashes, and determine whether acute alcohol and cannabis consumption increases the risk of a crash involving injury. This study is timely given recent legislative changes in Canada (expanding medical marijuana) and individual U.S. states, such as Colorado and Washington State (legalizing possession of small quantities of cannabis), that point to a likely increase in the prevalence of cannabis use in the general population.

Methods

Participants

Participants were non-fatally injured cyclists presenting to an emergency department after being involved in a traffic crash. Between April 2009 and June 2011, injured cyclists were recruited from three Canadian hospitals, capturing diverse patient populations (rural, urban, suburban, multi-ethnic, differing income and social class). The Queen Elizabeth II Health Sciences Centre in Halifax, Nova Scotia, is the largest adult tertiary care hospital in Atlantic Canada and the only adult tertiary care centre in Nova Scotia. St. Michael's Hospital in Toronto is an inner-city trauma centre with a high proportion of crashes involving major traumas. Humber River Regional Hospital in north-central Toronto is a large, acute-care hospital, with a crash patient population who largely suffer from less severe injuries. Participants were 16 years of age and older in Halifax, 18 years of age and older in Toronto, and must have presented to hospital within 24 hours of their crash. Participants were recruited using a probability time sampling strategy, with different four-hour time slots randomly selected, and with the probability of selection based on occurrence density (i.e. times with higher risk for occurrence of crashes had a greater chance of being selected) (Borges et al., 2006; Asbridge et al., 2014).

Study design

A case-crossover design was employed, which is well-suited for studies of transient effects on the risk of rare acute events (Dussault et al., 2002; Mura et al., 2003), and has previously been employed to study factors influencing crash risk (Redelmeier and Tibshirani, 1997; Soderstrom et al., 1995). With this design each subject serves as their own control, the strengths of which are a reduction in the impact of confounding from known and unknown sources and the elimination of control-selection bias (Mackenzie and Mittleman, 2000; Rothman and Greenland, 1998).

For the case period, cannabis and alcohol were assessed (through blood sample or self-report) within the six hours before the crash. For cyclists who consented to provide a blood sample, we defined acute cannabis and alcohol use as any THC level (>0.2 ng/ml) or any ethanol level (> 2.0 mmol/L). Our primary assessment of risk factor exposure was based on blood sample results, if present, and self-report results otherwise, and measured dichotomously.

The control condition necessary to quantify risk is established by asking cases about their past exposure. Two different control periods were used to determine past exposure (Dussault et al., 2002). For the first control condition, cannabis use and alcohol use were assessed retrospectively for the same time interval (i.e. six hours) during the last time the cyclist rode their bicycle around the same time of day. The second control condition was the self-reported usual frequency of cycling under the influence of cannabis and alcohol over the preceding six months (Yu et al., 2013). Unfortunately, a limitation of this study is that the case period draws on either biologic or self-report data, while the control period measures exposure only through self-report.

Interview

The interview drew on questions from the WHO Collaborative Study on Alcohol and Injuries (Borges et al., 2006), and assessed: 1) a socio-demographic driver/cyclists profile (age, gender, country of birth, education, employment status) and injury history; 2) events surrounding the crash (cannabis and alcohol use, time of crash, crash location, reason for crash, injury type, severity, and history); 3) cannabis use, alcohol use, and general driving information for the control period; 4) usual patterns of substance use over the past six months, including problem use measured through the CUDIT and AUDIT scales (Mercer and Jeffery, 1995). Blood samples were collected via an informed consent procedure and all blood analysis was completed at the laboratory at the Centre for Addiction and Mental Health in Toronto, Canada. All consenting cyclists received \$50 for participating in the study, irrespective of whether they completed the interview. Additional details on the study protocol can be found elsewhere (Asbridge et al., 2014).

Control for Confounding

In addition to the within-person design, we addressed potential confounding of other drugs with the inclusion of measured screening for the presence of benzodiazepines and cocaine, two drugs often found in studies of impaired cyclists.

Statistical analyses

We estimated conditional fixed effects logistic regression models to account for the within-person structure of the case-crossover approach (Maclure and Mittleman, 2000; Marshall and Jackson, 1993). Our main models measures cannabis impairment alone and alcohol impairment alone, identified either in blood or through self-report, if no sample was present. This was achieved by removing all cyclists who had used alcohol, benzodiazepines, or cocaine, to isolate the effect of cannabis on crash risk, and removing cyclists who had used cannabis, benzodiazepines, and cocaine, when looking at alcohol use and crash risk. We ran additional models looking at blood sample results only, self-report results only, and among all cyclists regardless of what combinations of cannabis, alcohol and other drugs were used. For the above analyses we employed our first control condition, substance use during the “last time driving”. We also analyzed our main models, measuring cannabis and alcohol alone, with a second control condition – “usual frequency”.

Ethical approval for this research study was obtained from all participating hospitals, universities, and centres, and all human participants gave written informed consent to participate.

Results

In total, 393 cyclists who presented to emergency departments in Halifax and Toronto due to a crash were included in the study. Ineligibility was due to young age, poor mental or physical competency, death, discharge or leaving without treatment, language barrier, or having a crash that occurred outside the study window, leaving us with a response rate of 73%. Of those eligible, 153 (39% of those consenting) agreed to provide a blood sample. Among all cyclists, 58 (14.8%; CI: 11.2-18.3) reported using cannabis prior to the crash and 57 (14.5%; CI: 11.0-18.0) reported pre-crash alcohol use; when restricted to the 153 cyclists who provided a blood sample, more than one in four (28.8%; CI: 21.5-35.6) had positive levels of THC and slightly higher than one in five (21.6%; CI: 15.0-28.1) had a positive blood alcohol level (Table 1).

INSERT TABLE 1

Relative to substance-free cyclists, those who used cannabis prior to the crash were, on average, younger (none over 65 years of age), more likely to be male (98%), Canadian-born (90%), had a high school education or less, and were more likely to be unemployed. Cyclists using alcohol prior to the crash were similar to those using cannabis, with the exception of being slightly older, on average, with a higher proportion foreign born, and with a higher rate of unemployment relative to those using cannabis. Cyclists who used cannabis prior to the crash had elevated rates of alcohol dependence (20.7%) and cannabis dependence (25.9%) relative to substance-free cyclists, while those who used alcohol pre-crash had elevated rates of alcohol dependence (22.8%) and, to a lesser extent, cannabis dependence (10.5%).

Cannabis and alcohol related cycling crashes were more likely to occur in the evening and at night (Table 1). No differences were observed between crashes involving alcohol or cannabis and those that did not, with respect to injury severity or crash location. Cyclists who used cannabis pre-crash were more likely to indicate being distracted or to have lost control of their bicycle as the reason for the crash; those who used alcohol pre-crash also cited distraction more often, but noted getting a tire stuck in a street car track or sewer grate as the most common reason for their crash. Cycling frequency was generally similar though a greater proportion of cyclists who had consumed cannabis or alcohol reported cycling greater distances in an average week.

In our cannabis regression models (Figure 1), cannabis use alone (i.e. without the use of other substances), identified by blood testing or self-reporting (Model 1a), was associated with an OR of collision of 2.38 (95% CI: 1.04-5.43). Upon restricting the analysis to those who provided a blood sample (Model 1d), cannabis was associated with an OR of 9.0 (95% CI 2.09-38.8). When the sample (Model 1c) included cyclists who had used

cannabis either alone or in conjunction with other drugs (alcohol, benzodiazepines, cocaine) the association was significant (OR 4.11; 95% CI: 1.98-8.51), with a higher odds ratio relative to crashes involving cannabis alone. When cannabis use in the case and control periods were measured via self-report only (Model 1e), cannabis use was not significantly associated with crash risk (OR 0.40; 95% CI: 0.12-1.27).

INSERT FIGURE 1

Turning to our alcohol regression models (Figure 2), alcohol use alone (Model 2a) was significantly associated with a higher risk of a cycling-related crash (OR 4.00; 95% CI: 1.64-9.78). This finding was consistent across all subgroups analysed, including whether alcohol exposure was measured through blood or self-report, and when alcohol was consumed with other substances (Models 2c-2e).

To further validate our findings we examined our main models using a second control period (Figure 1 Model 1b) replacing cannabis use during the last cycling event with whether the individual typically cycles after using cannabis (defined as at least once per month in the past six months, not counting the current crash). Here the association between cannabis use and crash risk was non-significant. When replacing alcohol use during the last cycling event with cycling under the influence of alcohol at least once per month in the past six months (Figure 2 Model 2b), the association was significant (OR 4.80; 95% CI: 1.83-12.6). No interactions between either cannabis nor alcohol and other covariates were observed.

Discussion

The role of substance use in bicycling related crashes is largely under-examined. While a handful of studies have noted the elevated crash risk posed by alcohol consumption (Martinez-Ruiz et al., 2013; Li et al., 2001; Olkkonen and Honkanen, 1990), no studies have looked at cannabis use among cyclists and related crash involvement. Our study offers two key findings: First, a substantial proportion of cyclists who were non-fatally injured in a crash had consumed either cannabis and/or alcohol in the preceding hours. Second, acute cannabis consumption and acute alcohol consumption significantly increased the risk of a cycling crash involving a non-fatal injury.

Nearly 15% of cyclists presenting to emergency departments in Toronto and Halifax indicated, either through blood or self-report, having consumed cannabis, with a similar proportion reporting pre-crash alcohol use. When restricted to blood sample results only, the proportions rose to nearly 29% for cannabis and 22% for alcohol. Little comparable data exists to contextualize these findings in North America, though a recent study of cycling fatalities in New York noted that alcohol was present in 21% of cases. While no comparable data on

cannabis use among cyclists exists, a number of epidemiological studies have reported on cannabis incidence in injured or fatally injured drivers where observed rates ranged from 9% to 20%, with higher rates noted in studies of fatal crashes (Dussault et al., 2002; Mura et al., 2003; Laumon et al., 2005; Soderstrom et al., 1995; Mercer and Jeffery, 1995; Cimbura et al., 1990; Stoduto et al., 1993). Our blood sample results suggest that cyclists may be more likely consumers of cannabis and alcohol relative to other road users.

We also found that both cannabis and alcohol independently increased cyclists' risk of being in a crash that led to a non-fatal injury and an emergency room visit, though the association varied depending on how substance use was measured. Our main models indicated that cannabis was associated with greater than two-fold increased odds of being involved in a cycling crash, with a stronger observed association when only blood sample results were considered. Sensitivity analyses revealed that when exposure status was based solely on self-report data, the association of cannabis with crash risk was non-significant. Alcohol use exhibited a stronger association (four-fold increase in the odds) with cycling crash risk, and, again, the strength of the association increased when only blood data were examined; alcohol results were also consistent in our sensitivity analyses. Equally important, the combined use of alcohol and cannabis enhanced the risk of a cycling crash above that which was observed by either substance alone; these findings speak to the potentially synergistic effects of the combined use of these substances in the context of fine and gross motor skills (Perez-Reyes et al., 1988).

Study Limitations and Strengths

This study suffered from two major limitations. First, while all respondents self-reported information on pre-crash substance use, only 39% of respondents consented to provide a blood sample to measure exposure status during the case period. This is problematic because pre-crash substance use rates were higher in blood samples than self-report, and for a number of individuals, blood sample and self-report indications of pre-crash substance use did not match. Thus, a number of positive cases were likely missed and under-reporting occurred. If we assume the under-reporting of substance use is restricted to the case period, our estimates of an association between cannabis use and crash risk would likely be conservative. However, a second major weakness is the differential measurement of exposure status in the case and control periods. As noted, in the case period, blood samples were drawn on a proportion of cyclists following their crash, yet exposure status during the control period was measured entirely by respondent self-report. In this situation, given that under-reporting is likely common in both the case and control periods, cyclists who indicated no substance use in the control period may have, in fact, used a substance. This biases our estimates away from the null, indicating that we have over-estimated the association of substance use with crash risk. Additional analyses confirm this bias. Removing all cases where blood sample and self-report results related to pre-crash substance use were discordant, the association between cannabis use and crash risk was non-significant (OR 0.50; 95% CI: 0.15-

1.66); for alcohol, the association remained significant (OR 2.83; 95% CI: 1.12-7.19). Under-reporting for alcohol use was less common and there were few discordant responses between self-report and blood measures for alcohol consumption. We suspect that lower levels of under-reporting for alcohol relative to cannabis relates to the illegal status of cannabis; drinking and driving is an illegal activity, alcohol use, per se, is not.

What are the implications of our findings on policy and programs directed at improving road safety? Given the limited evidence on the epidemiology of bicycling related crashes and injury, our findings provide seminal evidence that cannabis use while cycling may increase crash risk, while confirming the association of alcohol and crash risk among cyclist found elsewhere (Li et al., 2001). Why rates of cycling after using cannabis and alcohol are so high remains less clear but may point to at least two misconceptions held amongst cyclists. First, and foremost, bicyclists may not perceive alcohol and cannabis as impairing agents in the context of the safe use of a bicycle. For instance, in 2005 in Switzerland, a reduction in the legal BAC limit, from 0.08 g/dL to 0.05 g/dL, which applied to all vehicles, was associated with a significant reduction in alcohol-attributed motor vehicle crashes and fatalities in the years that followed; no reduction in bicycle related crashes and fatalities was observed (Siegrist et al., 2006). The dearth of research on substance use, in the context of cycling, means that very little information is available to health and government officials to direct public health messaging advocating against cycling while impaired. Moreover, there are distinct differences in how cannabis impairs driving performance relative to alcohol. The belief among users is that cannabis does not impair driving performance, or not as severely as alcohol, while those impaired by cannabis have trouble recognizing their own acute impairment (Davey et al., 2005; Donald et al., 2006).

Equally important is the inconsistency in the regulation of cycling while impaired by a psychoactive substance. While some U.S. states (i.e. California, Colorado), and other jurisdictions (e.g. Australia, United Kingdom, Poland, Switzerland, Germany) have made it is illegal to ride a bicycle while impaired by alcohol or drugs, this is not the case in Canada and most U.S. states. Amendments to the Canadian criminal code should be considered that equate penalties for cycling while intoxicated with those for driving while impaired. Finally, from a clinical perspective, given the presence of an alcohol or drug use disorder in many of the injured cyclists presenting to the emergency department, greater screening and brief intervention directed at injured cyclists may be warranted.

Conclusion

In conclusion, our study shows that substance use in the context of cycling may pose substantial individual harm and represents an important road safety concern. Our findings on alcohol's role in cycling crashes, along with previous studies that have shown an increased risk posed to cyclists from the consumption of alcohol, may

act as an impetus for policy makers to develop improved legislation directed at alcohol-impaired cycling, particularly in Canada and most of the United States where laws currently do not exist. The case for cannabis is less clear. While this is the first study to examine whether acute cannabis consumption increases the likelihood that a cyclist will be involved in a crash involving injury, findings were inconsistent across models and should be interpreted with caution. Additional data is needed, drawn from well-designed studies employing objective measures of acute cannabis consumption in the context of cycling. Finally, greater effort should be directed at reducing rates of cycling while impaired, through advocacy and education, to increase awareness among cyclists and other road users that the impairing effects of substances are not restricted only to those who operate a motorized road vehicle.

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Contributors: MA and CP did a background search of the published work. MA, RM, MC, JT, and JR designed the study, collected data, and analysed and interpreted data. MA and CP wrote the first draft. All authors revised the report.

Conflicts of interest: We declare that we have no conflicts of interest. This manuscript is an honest, accurate, and transparent account of the study being reported. No important aspects of the study have been omitted.

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