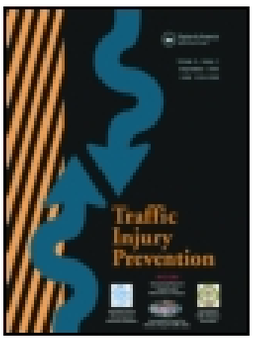

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Marijuana trajectories and associations with driving risk behaviors in Canadian youth

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ABSTRACT

Objective: Research on risky driving practices involving marijuana use among youth and young adults often relies on cross-sectional data, which fail to account for longitudinal changes in substance use patterns. A better understanding of the longitudinal patterns of marijuana use and its effect on risky driving practices during young adulthood is needed in order to better inform prevention efforts. The current study examined whether different longitudinal patterns of marijuana use across the transition from adolescence to young adulthood are associated with impaired driving risks in young adulthood.

Methods: Data were from the longitudinal Victoria Healthy Youth Survey, which interviewed youth biennially on 6 occasions across 10 years (2003 to 2013).

Results: Youth who reported consistently high levels of marijuana use from adolescence to young adulthood (chronic users) and youth who reported increasing levels of use across this period (increasers) were more likely to engage in risky impaired driving behaviors compared to the other 3 user groups (occasional users, decreasers, and abstainers). Frequency of marijuana use was also predictive of impaired driving risks in young adulthood after controlling for individual characteristics (age, sex, socioeconomic status, age of onset of marijuana use), frequency of other substance use (heavy episodic drinking and illicit drug use), and simultaneous use of marijuana and other substances (alcohol and illicit drugs). By young adulthood, youth who use marijuana more than once a week are more likely to simultaneously use alcohol and engage in heavy episodic drinking. They are also more likely take driving risks.

Conclusions: Harm reduction strategies and legislative approaches targeting impaired driving risks associated with marijuana use should include approaches to target these high-risk groups and to reduce simultaneous use of alcohol.

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Cannabis use; impaired driving; young adults; prevention

With the recent legalization of recreational marijuana in Canada, an evidence-informed approach to preventing marijuana-related driving risks is imperative. Marijuana use among Canadian youth aged 15 to 24 is more than double the prevalence in adults aged 25 and over (Statistics Canada 2015), and youth have higher rates of crashes associated with marijuana use (Brubacher et al. 2016). Formulating a youth-centered prevention approach requires a better understanding of the ways in which marijuana is used by youth, including how use patterns change over time and how differential patterns are associated with variability in impaired driving risks.

According to the developmental perspective on the etiology of antisocial behaviors (Moffitt 2008), some youth report using substances only during adolescence and desist as they enter young adulthood. Other youth, with an earlier age of onset and who continuously use substances across the life course, are more likely to have issues with dependency (Thompson et al. 2018). Long-term, repeated assessments of users are needed to detect problematic use patterns. However, studies involving marijuana and impaired driving risks often rely on cross-sectional data and do not account for the heterogeneity in use patterns. Given that the use of alcohol and illicit drugs predict vehicle crashes (Brubacher et al. 2016), it is also important to know how often marijuana is used with these substances and whether marijuana use adds to impaired driving risks. This study examines associations between longitudinal patterns of marijuana use and impaired driving risks in a large sample of Canadian youth to determine how different use patterns can help us better predict high-risk drivers.

Research has identified different patterns of marijuana use from adolescence to young adulthood. In addition to abstainers, there are groups of youth who report occasional

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use, decreasing use, increasing use, or chronic use (e.g., Terry-McElrath et al. 2017; Thompson et al. 2018). Past cross-sectional research with the current sample showed that chronic users took more driving risks but did not examine driving risks related to other patterns of marijuana use or account for the effects of the simultaneous use of marijuana with alcohol or illicit drugs (Leadbeater et al. 2017).

Motor vehicle crashes among adolescents are strongly linked to inexperience and distractions, such as peers and cell phones (Keating and Halpern-Felsher 2008). However, less research has examined impaired driving risks in young adulthood (aged 18 to 29) when youth are most likely to be fully licensed and driving independently. Young adulthood affords greater independence as youth enroll in postsecondary education or vocational training, live away from their parents, and embark on new careers. By the early 20s, alcohol use is legal and, for many, graduated licensing restrictions have ended. Though motor vehicle accidents remain the leading cause of death among youth, prevention strategies and public health messaging targeting marijuana use in young adult drivers in the context of a legal environment have not been considered (Solomon and Chamberlain 2014).

Marijuana use and driving

Canadian population surveys indicate that marijuana-impaired driving and the percentage of fatally injured drivers testing positive for drugs are rising (Robertson et al. 2017). In British Columbia, one third of fatally injured drivers and 30% of moderately injured drivers tested positive for drugs; marijuana was the most common drug found in young drivers (Brubacher et al. 2016). The Canadian Student Tobacco, Alcohol and Drugs Survey found that 9% of grade 11 to 12 students reported ever driving within 2 h of using marijuana and 20% of grade 9 to 12 students reported ever riding with a high driver (Minaker et al. 2017). In an Ontario-wide survey of students in grades 7 to 12, the past-year prevalence of driving under the influence of marijuana (16%) was higher than that of alcohol (12%; Cook et al. 2017).

Experimental studies involving driving simulations show that marijuana use can impair driving performance by reducing lateral control, reaction time, and overall driving ability (Downey et al. 2013). Reviews of epidemiological studies also suggest that the risk of motor vehicle collisions increases with marijuana use (Asbridge et al. 2012).

Several demographic factors are associated with risky driving involving marijuana. With a Canadian sample of grade 11/12 students, Minaker and colleagues (2017) found that older students, boys, and Aboriginal students had higher odds of driving after using marijuana. With an American sample, Terry-McElrath et al. (2014) found that high school students with heavy use rates and those who simultaneously used alcohol report more unsafe driving practices than their peers. Young adults who drive after using marijuana also report an early age of onset (Le Strat et al. 2015) and more dependence symptoms and are frequent users (Leadbeater et al. 2017).

Given that marijuana use is highest during young adulthood (Statistics Canada 2015), it is important to understand how use patterns predict driving risks in order to inform targeted, age-sensitive prevention and intervention efforts. To avoid overestimating the unique effects of marijuana on driving risks, it is also necessary to examine the co-use of other substances. In this study, we first examine how differences in the longitudinal patterns of marijuana use are related to substance use behaviors at ages 22 to 28. Next, we examine how different marijuana use patterns are associated with self-reports of driving or operating machinery while high on marijuana and of being in a car with a driver (including themselves) who had been using marijuana or alcohol. Finally, we assess the effects of marijuana use frequency on impaired driving risks beyond the effects of other risk behaviors.

Methods

Participants

Data from the Victoria Healthy Youth Survey were collected biennially 6 times between 2003 and 2013 in a medium-sized Canadian city. Participants' responses reflect their marijuana use patterns prior to legalization of cannabis in 2018. At baseline there were 662 youth aged 12 to 18 years old (M = 15.52; SD = 1.93; 52% females). Eighty-five percent of youth were European-Canadian, 4% were Asian, and 11% were other ethnicities. Nineteen percent of fathers and mothers finished high school only, and 43% of fathers and 49% of mothers completed postsecondary training.

Retention rates were high: 87% (T2), 81% (T3), 69% (T4), 70% (T5), and 72% (T6). Attrition analyses compared youth who remained in the study by T6 ($n = 478$) and those who did not ($n = 184$) on T1 demographic and study variables. Participants who remained were more likely to be female, χ^2 (1, 662) = 8.77, $P = .003$, and had slightly higher T1 socioeconomic status (SES; M = 6.69, SD = 1.71), F(1, 659) = 21.72, $P < .001$, compared to nonparticipants (M = 5.97, SD = 1.96). There were no mean differences on any of the key study variables.

Procedure

Youth and one parent/guardian (if <18 years of age) provided consent for participation at each wave. Youth received a gift certificate at each interview. Individual interviews took place in the youth's home or another private place. To enhance privacy and increase response rates, some questions were strictly self-report. These items dealt with private topics for which youth are the best sources of data (e.g., sexual experiences, substance use, etc.).

Measures

Substance use

Marijuana. Participants were asked, "How often did you use marijuana in the past 12 months?" on a 5-point scale: 0 =

never, 1 = *a few times a year*, 2 = *a few times a month*, 3 = *once a week*, and 4 = *more than once a week*. Additionally, the amount used in one day was reported in response to the question, "During the last 3 months, on a day when you used marijuana or hashish roughly how many joints did you usually have in that day? (Count 10 puffs, five bong or pipe hits, or 1/2 gram as equivalent to one joint)."

Heavy episodic drinking. Participants responded to the question, "How often in the past 12 months have you had five or more drinks on one occasion?" as 0 = *never*, 1 = *a few times a year*, 2 = *a few times a month*, 3 = *once a week*, and 4 = *more than once a week*. The definition of a standard drink was provided.

Illicit drug use. Participants responded to the question, "How often in the past 12 months have you had used any of the illicit drugs (i.e., cocaine, hallucinogens, amphetamines, and club drugs)?" as 0 = *never*, 1 = *a few times a year*, 2 = *a few times a month*, 3 = *once a week*, and 4 = *more than once a week*.

Marijuana and simultaneous use with other substances. Participants indicated the frequency with which they used marijuana with alcohol and any of the illicit drugs (i.e., cocaine, hallucinogens, amphetamines, and club drugs) within a 3-h period in the last 6 months. Responses were recoded as 0 = *never* and 1 = *ever in the past 6 months*.

Substance use risk behaviors

Marijuana. Participants responded to the following: (1) "In the past 12 months, have you been high or intoxicated from marijuana more than once in any situation where you were physically at risk (e.g., driving a car, riding a motorbike, using machinery, boating, etc.)?" and (2) "In the past 30 days, how many times were you in a car or other vehicle when the driver (including yourself) had been using marijuana or other drugs?" For each question responses were coded as 0 = *no/never* or 1 = *yes/ever*.

Alcohol. Participants responded to the question, "In the past 30 days, have you been in a car or other vehicle when the driver (including yourself) had been drinking alcohol?" Responses were coded as 0 = *never* or 1 = *ever*.

Data analytic strategy

Longitudinal patterns of use

Using latent class analysis to empirically extrapolate groups of individuals based on their longitudinal patterns of use from age 15 to 28 (see Thompson et al. 2018), youth were classified as abstainers (29%; who never used in the last year), occasional users (27%; abstained in adolescence and increased use to a "few times a year" after age 17), decreasers (14%; used a few times per month at age 15 and decreased to no use by age 23), increasers (20%; used occasionally in adolescence and increased rapidly, peaking at more than once per week about age 22 and then started to decline), and chronic users (11%; used more than once per week across all ages). The significance of differences in the demographic variables, substance use behaviors, and in the frequencies of impaired driving risks at T6 (aged 22 to 28) were assessed.

Logistic regression models were then used to predict the likelihood of being in a vehicle when the driver had been using (1) marijuana and (2) alcohol. Analyses were conducted at T6 when participants were between 22 and 28 years old. Variables included in the model were demographic variables (e.g., age, sex, SES), age of onset for marijuana use, frequency of marijuana use, heavy episodic drinking and illicit drug use, and simultaneous use of marijuana with alcohol and illicit drugs. Each variable was first examined separately to determine their independent associations with impaired driving risks (controlling for demographic variables). Then all variables were included simultaneously to determine their concurrent effects on driving risks.

Results

Demographic differences

Increasers and chronic users were more likely to be males, and abstainers, decreasers, and occasional users were more likely to be female (Table A1, see online supplement). Increasers and chronic users had lower SES than the other user groups. Chronic users also had the lowest levels of T1 mother's education and a lower age of onset for marijuana (age = 13.28, SD = 1.98) compared to abstainers, occasional users, and increasers.

Substance use

Increasers and chronic users reported higher frequency and quantity of marijuana use and greater use of other substances compared to the other user groups (Table A1). Specifically, at T6, increasers and chronic users were more likely to report using marijuana more than once a week (38 and 71%, respectively) and reported higher quantity of marijuana use (1.27 and 2.60 joints per average use, respectively), greater heavy episodic drinking, use of more illicit substances, as well as simultaneous use of these substances with marijuana compared to the other 3 user groups. Similarly, more youth in the increasers and chronic user groups met criteria for both alcohol (52 and 67%, respectively) and marijuana use (32 and 59%, respectively) disorders.

There were also notable differences in the various substance use behaviors between the occasional users, decreasers, and abstainers. Occasional users and decreasers reported engaging in heavy episodic drinking and illicit drug use more frequently than abstainers. Occasional users were more likely to report engaging in the simultaneous use of marijuana, alcohol, and illicit drugs than decreasers (51 vs. 11% for simultaneous marijuana and alcohol; 10 vs. 2% for simultaneous marijuana and illicit drugs, respectively). More

Table 1. Driving risk behaviors comparing abstainers, occasional users, decreasers, increasers, and chronic users at T6 (young adulthood ages 22–28).[a]

Driving questions at T6 (age 22–28)	Marijuana use trajectory groups				
	Abstainers (n = 183) (%)	Occasional users (n = 172) (%)	Decreasers (n = 89) (%)	Increasers (n = 127) (%)	Chronic users (n = 69) (%)
Past 12 months: High or intoxicated from marijuana more than once while physically at risk	0a,b	11a	0a,b	34c	42c
Past 30 days: Been in a car or vehicle after using marijuana or other drugs	5b	24a	9a,b	51c	71c
Past 30 days: Been in a car or other vehicle after drinking alcohol	18a	30a,b	24a,b	35b,c	56c

[a]Physically at risk can include driving a car, riding a motorbike, using machinery, boating, etc. Been in a car or vehicle can include being a driver or passenger. Entries with different lettered superscripts are significantly different from each other ($P < .05$). Percentages may not equal 100% due to rounding.

occasional users met criteria for marijuana use disorder than decreasers (13 vs. 0%, respectively).

Longitudinal patterns of marijuana use and associations with impaired driving risks

Chronic users were most likely to report all risky driving behaviors compared to the other user groups (occasional users, decreasers, or abstainers) except increasers (see Table 1). Specifically, 42% of chronic users reported that they have been "physically at risk" while high or intoxicated, 71% had been in a car when the driver (including themselves) was using marijuana, and 56% had been in a car when the driver (including themselves) had been drinking. Compared to chronic users, fewer increasers reported having been physically at risk while high or intoxicated (34%), in a car with a high driver (51%), or in a car with a drinking driver (35%), but these differences were not statistically significant. Impaired driving risks for increasers were also significantly higher than those of other user groups (i.e., occasional users, decreasers, or abstainers).

Predictors of impaired driving risks during young adulthood

Independently, each substance use variable was associated with marijuana-related driving risks at T6 (Table A2, see online supplement). Specifically, a younger age of onset, higher frequency of marijuana use, heavy episodic drinking, illicit drug use, and simultaneous use of marijuana with alcohol and illicit drugs were associated with higher odds of engaging in marijuana-related driving risks. Similarly, all substance use variables were independently associated with alcohol-related driving risks, except age of onset.

In the final model (with all variables together; Table 2), frequency of marijuana use was associated with twice the odds of driving (or being a passenger) in a car with a high driver, after accounting for demographics and other substances used concurrently or simultaneously. Marijuana use frequency did not uniquely predict being in a car with a driver using alcohol. However, use of illicit drugs was associated with twice the odds of driving (or being a passenger) in a car after drinking alcohol. Demographic factors and simultaneous use of marijuana and other substances did not predict risky driving behaviors, beyond other variables in the model.

Discussion

This study sought to determine how longitudinal patterns of marijuana use predict impaired driving risks in young adulthood. Our findings demonstrate that impaired driving risk behaviors are particularly high among youth with high-risk patterns of marijuana use (i.e., increasing or chronic use). The group of youth characterized by chronically elevated levels of marijuana use comprised 11% of the sample, and the group that increased across this period comprised 20%. In young adulthood, these youth used substances more frequently and combined substances with marijuana more often compared to the other 3 user groups (abstainers, decreasers, or occasional users). These youth were also more likely to report using machinery or driving while high. In addition, the percentage of youth driving or being a passenger in vehicle where the driver had been using marijuana or alcohol was higher among chronic users and increasers than any other user group. Targeted efforts to reduce driving risks in these groups, which comprise 30% of a community-based sample, are warranted. Clear messaging about the risks of driving after using marijuana and of co-use of alcohol and driving is needed. Early education to prevent adolescents from becoming high-risk users may also be effective in reducing use in young adulthood.

The higher prevalence of driving risks among chronic users and increasers is consistent with other studies that have demonstrated cross-sectional links between frequent marijuana use and driving (Leadbeater et al. 2017; Le Strat et al. 2015). The current study extends the literature by demonstrating how differences in the longitudinal pattern of marijuana use are associated with simultaneous use of multiple substances as well as with substance-related impaired driving behaviors in young adulthood.

Young adults who use marijuana frequently are more likely to underestimate the harms of use as well as the severity of their impairment when driving (Aston et al. 2016).

Table 2. Final logistic regression model accounting for all variables related to the odds of being in a car or other vehicle when the driver had been using marijuana or alcohol at T6 when youth were 22–28 years old.

	Risky driving: Marijuana				Risky driving: Alcohol			
Predictors	B	SE	Odds ratio	(99% Confidence interval)	B	SE	Odds ratio	(99% Confidence interval)
Demographics								
Sex	−0.05	0.29	0.96	(0.46–2.01)	−0.05	0.24	0.95	(0.52–1.75)
Age	−0.04	0.08	0.96	(0.79–1.16)	0.00	0.06	1.00	(0.85–1.17)
Mother's education	−0.14	0.11	0.87	(0.65–1.16)	0.05	0.10	1.05	(0.82–1.33)
Youth's SES	0.03	0.08	1.03	(0.84–1.26)	−0.02	0.07	0.98	(0.83–1.16)
T6 frequency of substance use								
Marijuana age of onset	−0.07	0.06	0.93	(0.80–1.08)	0.05	0.05	1.05	(0.93–1.18)
Marijuana	0.90**	0.13	2.45	(1.78–3.38)	0.02	0.11	1.02	(0.78–1.34)
Heavy episodic drinking	0.10	0.14	1.11	(0.78–1.57)	0.12	0.11	1.13	(0.85–1.50)
Illicit drug use	−0.03	0.35	0.97	(0.39–2.38)	0.73*	0.29	2.07	(0.99–4.32)
T6 simultaneous use of marijuana with other substances								
With alcohol	0.27	0.36	1.31	(0.52–3.28)	0.50	0.31	1.65	(0.75–3.63)
With other illicit drugs	0.07	0.43	1.07	(0.36–3.23)	0.31	0.37	1.36	(0.53–3.48)

*P < .05.
**P < .01.

Qualitative studies found that youth believe that driving after using marijuana is safe or safer than driving after using alcohol (McKiernan and Fleming 2017), and these misperceptions are associated with higher odds of marijuana-impaired driving behaviors (Aston et al. 2016). Chronic marijuana users may develop partial tolerance to the impairing effects of cannabis, leading them to underestimate driving risks. Use patterns characterized by chronic, high stable, and increasing levels may also reflect increasing dependence, which may also increase tolerance and contribute to impaired driving at high levels of use. In this sample, the increaser and chronic groups were more likely to meet clinical criteria for alcohol and marijuana use disorders compared to the other user groups.

The continuity of marijuana use across a decade in the chronic and increasing user groups suggests that it may be difficult for many young adults to prioritize quitting or reducing use. Young adults are less motivated to quit marijuana than cigarettes perhaps due to the misperception that marijuana holds fewer negative health consequences (Masters et al. 2018). Although subjective impairment of feeling high may be a poor indicator of risk, alternatives do not currently exist for self-monitoring. Public education regarding specific guidelines for how much marijuana users can smoke or ingest before driving is needed.

Secondary interventions are needed to identify early indicators of dependence and clarify misperceptions about the harms related to marijuana use. Brief interventions involving information, awareness, or motivational components that target young adult heavy users are promising (Fischer et al. 2013). Screening and brief motivational interviews could be added to protocols for youth arrested for impaired driving and emergency departments who receive youth injured in vehicle crashes.

During young adulthood when youth were 22–28, those who used marijuana more frequently were 2 times more likely to drive after using marijuana or ride with a driver who had used marijuana, after considering individual characteristics, frequency of other substance use, and simultaneous use of marijuana with other substances. This suggests that the unique effect of frequent marijuana use on risky driving practices is significant. Although independently each substance use risk variable was associated with driving risks, the finding that age of onset, frequency of use of other substances, and simultaneous use of marijuana with other substances do not predict driving risks over and above frequency of use is surprising because previous studies have demonstrated associations with risky driving practices (Le Strat et al. 2015; Minaker et al. 2017; Terry-McElrath et al. 2014). However, these studies are typically cross-sectional and focused on younger samples.

Limitations

The current study has notable strengths such as the longitudinal design spanning across a decade. However, generalizability of findings is limited to British Columbia, Canada, where the prevalence of marijuana use among youth may be higher (17.3%) than in other provinces (range among other provinces = 8.2 to 14%; Statistics Canada 2015). Moreover, our study does not distinguish between risks incurred as passengers or drivers. However, previous studies have found that users of marijuana are also more likely to be passengers in vehicles where the driver had been using marijuana (Minaker et al. 2017), likely because they tend to affiliate with peers who are also heavy users.

The variables examined in the current study do not tap the multiple co-occurring risks that can affect driving behaviors. Driving under the influence of marijuana is embedded in socioecological contexts that include individual, interpersonal, and community factors. For example, social factors such as having more friends who use can impact the likelihood of driving after using marijuana (Berg et al. 2018). These findings warrant further examination into the interactive role that other macrolevel factors may play in predicting marijuana-impaired driving.

Despite these limitations, our findings suggest that following legalization in Canada, the risk of driving under the influence of marijuana, especially among this age group, may increase, as it has following state-level marijuana legalization in the United States (Salomonsen-Sautel et al. 2014). Enforcement and testing for drug-impaired driving, as well as prevention and intervention programs, lag behind the

resources available for managing alcohol-related problems (Solomon and Chamberlain 2014). Given the high level of co-use, alcohol strategies that have worked to reduce youth alcohol consumption and driving may also be effective in reducing marijuana use and driving (e.g., designated driver campaigns, zero tolerance for new drivers, and limiting peers in car). Screening for and offering interventions for marijuana dependency in youth involved in vehicle collisions may also help reduce risks. As Canada adjusts to the legalization of cannabis, public obligations to anticipate and implement strategies to reduce driving risks among youth are increased.

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