Wilkins *et al. Harm Reduction Journal* (2024) 21:192
https://doi.org/10.1186/s12954-024-01111-w

Harm Reduction Journal

RESEARCH Open Access

Exploring the substitution of cannabis for alcohol and other drugs among a large convenience sample of people who use cannabis

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Abstract

Background The substitution of cannabis for alcohol and other drugs has been conceptualised in a harm reduction framework as where cannabis is used to reduce the negative side-effects, addiction potential, and social stigma of other drugs. There is currently mixed evidence with recent reviews suggesting cannabis co-use patterns may vary by age and ethnicity. Yet few studies have had large enough samples to examine this demographic variation in detail.

Aims To explore the co-use of cannabis with alcohol and other drugs within demographic subgroups of a large sample of people who use cannabis. Specifically: (1) whether cannabis is being substituted for other drugs, and (2), whether cannabis use leads to more, less or the same level of other drug use.

Method Online convenience survey promoted via Facebook™ completed by 23,500 New Zealand respondents. Those who had used cannabis and any of eight other substances in the same six-month period were asked if their use of cannabis had any impact on their use of each other substance ("a lot more", "little more", "no impact/same", "little less", "a lot less"). Frequency and quantity used of each other drug was compared by co-use group. Generalised logistic regression models were developed to predict co-use categories.

Results Significant proportions reported cannabis use led to "less" alcohol (60%), synthetic cannabinoid (60%), morphine (44%) and methamphetamine (40%) use. Those who reported using "less" had lower frequency and amount used of other drugs. Approximately seven-out-ten reported cannabis use had "no impact" on LSD, MDMA, and cocaine use. One-in-five reported using cannabis led to "more" tobacco use. Young adults (21–35-years) were more likely to report cannabis use led to "less" drinking and methamphetamine use. Adolescent co-users (16–20 years) reported mixed impacts. Māori were more likely to report cannabis use resulted in "less" alcohol, tobacco, methamphetamine, and LSD use. Students and those living in cities were less likely to report cannabis use lowering use of other substances.

Conclusion Cannabis and other drug co-use patterns are moderated by life stages, lifestyles, cultural perspectives, and urbanicity. Harm reduction initiatives and policy reforms should take account of these moderating factors.

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Keywords Cannabis, Cannabis substitution, Alcohol, Co-use, Methamphetamine, LSD, MDMA, Tobacco

Background

New Zealand has an unusual drugs market compared to many other developed countries, reflecting its geographic isolation and small population [1–3]. While the availability of cannabis and methamphetamine is high by international standards, due to significant domestic cannabis cultivation and the large-scale importation of methamphetamine from proximate Asia, the availability of cocaine, MDMA and heroin is low reflecting the distance from key producer regions and related international trade routes [1–5]. People who inject drugs in New Zealand have historically used morphine diverted from the domestic health system rather than internationally sourced heroin [1, 3], and consequently, use of heroin and other illegally sourced synthetic opioids, such as fentanyl, is low for now [2].

While cannabis remains prohibited in New Zealand, the number of arrests has declined over recent decades and informal and formal police warnings and court diversion have been introduced, substantially reducing rates of convictions [6]. Nevertheless, there has been long standing campaigning for cannabis law reform to address the lifetime negative impacts of receiving a criminal conviction for cannabis and the disproportionate arrest and conviction of Māori (the indigenous people of Aotearoa New Zealand) for cannabis offences [1, 7]. This sustained advocacy cumulated in 2020 with the holding of a national referendum on the legalisation of recreational cannabis use and supply [8], which was narrowly rejected (50.7% reject, 48.4% in favour, 0.9% invalid) [9].

The quality of the New Zealand cannabis referendum debate was often poor reflecting gaps in evidence about the consequences of legalisation both in New Zealand and internationally where reforms have been implemented [9]. The referendum generated considerable expert and public debate about the potential merits of cannabis legalisation, including harm reduction opportunities to reduce the health risks of cannabis via regulated manufacture and opportunities to limit access to youth through retail outlet restrictions [9]. One consequence that received little attention was the potential impact cannabis legalisation may have on the consumption of alcohol, tobacco and other drugs [8]. International debate concerning cannabis legalisation also similarly often neglects the possibility of legal cannabis reducing the use of alcohol and other drugs and related harm. Alcohol use remains a substantial public health burden in New Zealand as in many other countries. No New Zealand studies of cannabis co-use have been completed to date. We have previously investigated whether police arrestees were substituting synthetic cannabinoids for natural cannabis in New Zealand and found only modest reductions in natural cannabis use [10].

The substitution of cannabis for alcohol and other drugs has been conceptualised in a harm reduction framework as instances where cannabis is used to reduce the negative side-effects, dependency potential, and social stigma associated with the use of other drug types [11]. The substitution of cannabis for alcohol, prescription, and other drugs has been documented among medicinal cannabis patients in the harm reduction literature on several occasions. For example, studies have found 40% [11], 41% [12], 52% [13], 25% [14], and 42% [15] of medicinal cannabis dispensary patients reporting substituting cannabis for alcohol. Many of these harm reduction studies did not consider if cannabis could also be combined with alcohol and other drugs as complements [16], either to enhance overall effects [17] or more pragmatically, intoxication from the use of one drug leads to use of an additional drug, or greater availability or more permissive attitudes encourage wider poly drug use [17, 18], with important implications for overall drug harm [19–25].

Reviews of existing studies of cannabis co-use have found mixed findings, with some suggesting cannabis is a substitute while others suggesting it is a complement for alcohol [16, 21, 26, 27]. For example, Risso et al. [16] found 30 of the 65 studies reviewed supported substitution, 17 supported complementarity, 14 did not find evidence for either, and four had evidence for both substitution and complementarity [16]. A key insight from these reviews has been that cannabis and alcohol co-use may vary by demographic characteristics and use patterns, for example adolescents versus adults, males versus females, frequent versus occasional users, or between ethnic groups [16, 21, 26–29]. For example, Saffer and Chaloupka [28] found cannabis decriminalization was associated with an increase in alcohol use among African American and White males, but conversely a decrease in drinking among Native Americans and Hispanics. Despite a number of jurisdictions legalizing recreational cannabis in recent years, the impact of legalization on other drug use is largely not accounted for in the existing literature reviews due to the relative recency of implementation. Early U.S. studies suggested that cannabis legalisation may be associated with reduced rates of opioid overdose [30]. However, subsequent modelling has suggested these findings are not robust to changes in the analysis period, with subsequent research yielding ambiguous or deleterious associations, likely related to the emergence of fentanyl and higher rates of overdose [31, 32]. While the impact cannabis legalisation has had on the opioid crises remains complex, cannabis might

still hold potential as an adjunct or alternative treatment for opioid use for certain individuals [33].

Reviews of the cannabis and alcohol co-use literature to date have noted that many existing studies undersample high-risk drug users and pool cross-sectional data which may mask the heterogeneity of substitution effects within population subgroups [27] and this limitation has also been noted in more recent studies [34–36]. Policy studies of cannabis co-use often rely on drug prevalence measures rather than more detailed data on the frequency and amount used of different substances [27]. Harm reduction studies have been limited to samples of medicinal cannabis patients in dispensary contexts and have largely been conducted in the U.S. and Canada [16] with only one notable exception in Europe [37]. Reviews have also noted that many harm reduction studies have not considered the possibility of complementary as well as substitution effects, with important implications for overall harm [16]. Existing co-use studies have overwhelmingly examined the impact of cannabis use on alcohol, tobacco, and prescription drug use, reflecting the high population prevalence of these substance and their known incidence of co-use with cannabis. Few studies have explored the impact of cannabis use on other drug types, such as methamphetamine, MDMA or LSD. All the recent literature reviews have highlighted the need for further research, particularly within demographic subgroups.

The aim of this present study was therefore to explore the co-use of cannabis with alcohol and a range of other drugs among a large sample of people who use cannabis to identify differences in co-use patterns among subgroups of people who use cannabis. Specifically, we aimed to determine: (1) whether cannabis is being substituted for other drugs, and (2), whether cannabis use leads to more, less or the same level of use of other drugs. The focus of the analysis was on the co-use of cannabis with the drug types most widely used in New Zealand, namely alcohol, tobacco, methamphetamine, MDMA and LSD, although some results are presented for less prevalent drug types, such as cocaine, synthetic cannabinoids, and morphine.

Methods

Survey design

The New Zealand Drugs Trends Survey (NZDTS) is an anonymous online convenience survey conducted annually to provide a "snapshot" of recent drug use and drug market trends in New Zealand. The NZDTS has been conducted annually since 2017/18, achieving very large samples, with findings and statistical analyses informing a range of drug related issues [4, 5, 38, 39]. Participation is promoted via Facebook advertisement campaign that targets those 16 years or older, living in New Zealand, and who express interest in a range of entertainment activities associated with higher incidence of alcohol and other drug use, including as alcoholic beverages, music genres, and night time entertainment events and venues [40]. No incentive payment is offered to participate.

The 2020 NZDTS survey was promoted from 24 January 2020 until 19 May 2020. A total of 26,121 people clicked on the link and began the survey. All surveys were audited for quality and extent of completion. Those who completed less than 15% of the questions (i.e., typically completing only the demographic section), who did not report their age, or reported an age outside of the 16–90-year-old range, were removed. To avoid compromising anonymity, respondent IP addresses are not stored, rather a custom software solution was utilised to convert IP addresses into non-reversible number. Survey responses with the same number were then flagged as potential duplicates and checked for demographic similarities and extent of completion to determine if they had been submitted by the same person. In cases where demographics matched, the most complete survey response was kept and any other removed. If demographics differed both responses were kept reflecting cases where two or more people in the same household completed the survey on the same device.

Following the above quality auditing process, a total of 2,621 responses were removed (i.e., 110 identified as a duplicate, 826 insufficient survey completion, and 1,685 outside of the age range) leaving a total of 23,500 completed surveys. The median time to complete the survey was 17 min. The conduct of the NZDTS was approved by the Massey University Human Ethics Committee (Application code: SOA 17/43).

Measures

Demographics

Respondents were asked about a range of demographic variables including age (i.e., years), gender (i.e., female, male, gender diverse), ethnicity (i.e., Māori [the indigenous people of Aotearoa New Zealand], European, Pacific, Asian, Other), highest educational achievement (i.e., none, primary/intermediate, high school, polytech/trade, university), employment status (i.e., student, employed [part/full], unemployed, sickness, retired/parenting/care-giving) and community size (i.e., city, small town, rural area).

Frequency of use

Respondents were asked whether they had used a range of drug types in the past six months, including alcohol, tobacco, cannabis, methamphetamine, MDMA, LSD/psychedelics, morphine (heroin is not widely available in New Zealand), synthetic cannabinoids, and cocaine. For each drug type reported used in the past six months,

respondents were asked how frequently they had used the drug in the past six months and were provided four options (i.e., 1–2 times in past six months, monthly, 1–2 times per week, daily or near daily).

Quantity consumed

For each drug reported used, respondents were asked how much of the drug type they had used on a "typically occasion" and were given customized quantity options for each drug type based on previous New Zealand drug research. For example, the cannabis consumption categories included number of "joints", "grams" and "cones". For alcohol, respondents first selected the alcohol type they drank (i.e., wine, beer and/or spirits) and then the number of "standard drinks" they consumed on a typical occasion. Respondents were provided with the official definition of a standard drink (i.e., "330 ml can of beer @ 4%, or 100 ml glass of wine @ 12.5%, or 30 ml shot of spirit @ 42%"). For tobacco, respondents reported the number of cigarettes they smoked per day. For methamphetamine, respondents reported the number of "points" (i.e., 0.1 gram) they used, and for MDMA they reported number of "pills" and/or "milligrams" they used. LSD consumption was reported in number of "tabs".

Substitution of cannabis for other drugs

We previously developed a co-use question to understand the impact of the emergence of synthetic cannabinoids on levels of natural cannabis use by police arrestees which was validated with use patterns [10] and so we adapted this question for the present survey. Those respondents who reported using cannabis and any of the eight other drug types (i.e., alcohol, tobacco, methamphetamine, MDMA, LSD/psychedelics, morphine/heroin, synthetic cannabinoids, cocaine) in the previous six months were asked: "Does using cannabis mean you use more/less or same of [each other drug]". The question was asked separately for each other drug type the respondent had previously reported using in the previous six months. The answer options were: "a lot more", "little more", "no impact/same", "little less", "a lot less"

Analysis

The above co-use categories were collapsed into "more", "same/no impact" and "less" groups as only very small numbers of respondents reported using "a lot more" of any drug type. Generalised logistic regression models for polytomous response were used to find variables to explain the co-use categories. The "same/no impact" group was used as the reference category and compared to the two other co-use alternative groups (i.e., "more" or "less"), and to the "no current cannabis use" group for each other drug type. A "no current cannabis use" group was included in the analysis as we wanted to compare those who used cannabis and reported various substitution/complementary impacts with other drug use (i.e. more, less, same) with those who used the other drugs but did not use cannabis. As outlined in the results below, this revealed that those who only used alcohol (no current cannabis) drank less alcohol than all the groups that used cannabis, regardless of the reported impact of cannabis on their alcohol consumption.

Five separate generalised logistic regression models were developed to predict co-use patterns of cannabis with alcohol, tobacco, methamphetamine, MDMA, and LSD, respectively. Due to low numbers of co-users of cannabis and synthetic cannabinoids, morphine, and cocaine in the New Zealand sample we could not run the models for these drug types. The five models were separated by drug type to better account for different consumption patterns, as well as the socio-demographic characteristics of the different people who use each drug type. Variables that predicted co-use categories included cannabis use patterns (i.e., frequency and quantity used on typical occasion) while controlling for all the demographics factors described above.

The frequency of drug use was coded slightly differently for different drug types as some drug types were used less frequently than others (e.g., daily or near daily use of LSD and MDMA was very rare). In all frequency of use comparisons, the category "once or twice in the past six months" was used as the reference category as this category represented the lowest frequency of consumption. For alcohol, tobacco and methamphetamine, "daily or near daily", "once or twice a week", and "monthly" use was compared to the reference category. For MDMA, three frequency categories were compared, i.e., "once or twice a week or more often", "monthly" and "once or twice in the past six months", and in the case of LSD two categories were compared: "monthly or more often" versus "once or twice in the past six months".

The quantity of drug use on a typical occasion was included as a continuous variable for each drug type. The drug quantity units were specific to each drug as explained above. Number of standard alcohol drinks consumed was transformed to the power 0.25 by using the Box-Cox method to avoid skewness in the distribution.

The demographic variables including age were categorised using dummy variables. Age groups 16–20, 21–25, 26–35 and 36+ (reference) were considered for the drugs alcohol, tobacco, methamphetamine and MDMA. For LSD, three categories were compared, 16–20, 21–25 and 26+ (reference). Age was categorised, rather than included as a continuous variable to avoid the inclusion of polynomial terms or smoothing functions (e.g., splines), and to better facilitate the interpretation of results across drug types co-used.

Ethnicity was categorised using dummy variables for the groups "Māori", "NZ European" (reference) and "other ethnicity". Employment status was fitted as dummy variables for the groups "student", "employed" (reference), and "unemployed/others". Highest level of education achievement was grouped by tertiary education (i.e., university, polytechnic, trade school), designated as "high" educational achievement, versus lower levels of education (i.e., high school, primary/intermediate, none), designated as "low" educational achievement. The geographical variables included were the 16 New Zealand regions and town size variable (0="rural area" or "small town" versus 1="city").

Covariates were kept in the generalised logistic regression models if they were statistically significant ($p<0.05$). The goodness of fit for all the generalised logistic regression models was assessed using the Hosmer and Lemeshow test [41]. Where there was missing data, it was addressed by listwise deletion. All analysis was undertaken using SAS software (version 9.4).

Results

Self-reported co-use relationships between cannabis and other drugs

The drug types most often used by the sample in the past six months were alcohol (87%), cannabis (68%), tobacco (57%), MDMA (45%), LSD (26%), cocaine (12%), methamphetamine (7%), morphine (2%) and synthetic cannabinoids (1%). 76% of the cocaine users had only used 1–2 times in the past six months (consistent with the unique features of the New Zealand drugs markets as discussed in the Background). 98% of the people who used cannabis had also used one of the eight other drug types in the same six-month period (i.e., alcohol, tobacco, methamphetamine, MDMA, LSD, synthetic cannabinoids, cocaine, and morphine) ($n=15,690$). The drug types most used with cannabis in the same six-month time frame were alcohol (96%), tobacco (72%), MDMA (59%), LSD (37%), cocaine (15%) and methamphetamine (10%). Very low proportions of the people who used cannabis reported using cannabis with morphine (3%) or synthetic cannabinoids (2%) during the same six-month period.

Figure 1 presents the self-reported impact of cannabis use on the use of these eight other drug types by the collapsed co-use categories (i.e., "less", "no impact/same", "more"). The other drug types which the highest proportion reported using "less" of due to their cannabis use were alcohol (60%), synthetic cannabinoids (60%), morphine (44%), and methamphetamine (40%). Approximately seven out of ten reported their cannabis use had "no impact" on their level of LSD (73%), cocaine (70%) or MDMA use (68%). In contrast, only 30% reported cannabis use had "no impact" on their level of synthetic cannabinoid use. Only minorities reported that cannabis use had led to "more" use of alcohol, methamphetamine, MDMA, cocaine, and LSD. The outlier was cannabis and tobacco co-use, where 22% reported that using cannabis use increased their level of tobacco smoking.

Demographic profile and drug use patterns by cannabis and other drug co-use groups

Table 1 breaks down the demographic characteristics and substance use of each cannabis co-use group and the non-cannabis group for alcohol, tobacco, methamphetamine, MDMA, and LSD users (i.e., 0=no-cannabis use, 1=cannabis use and "less" other drug, 2=cannabis

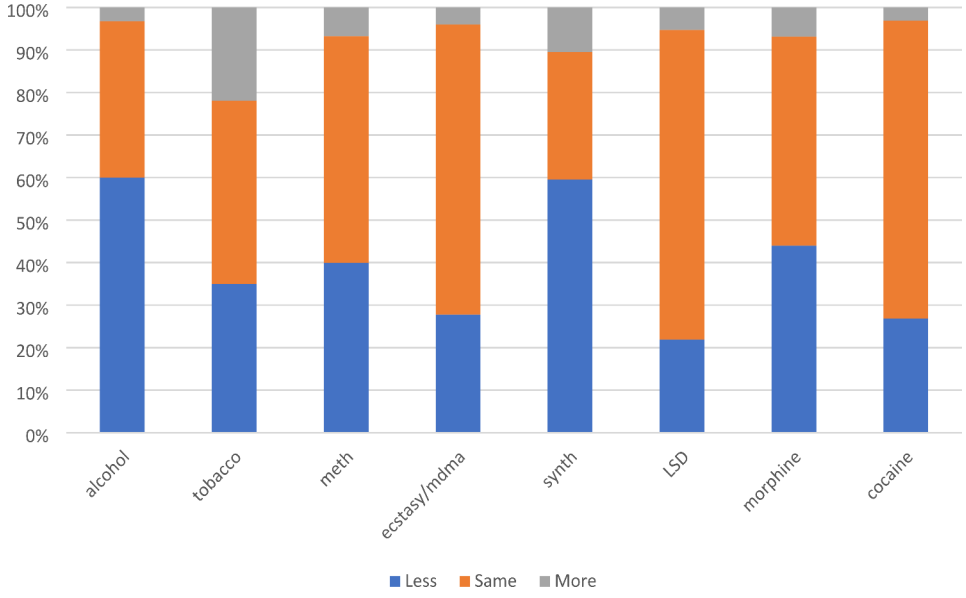

Fig. 1 Impact of cannabis use on the use of eight other drug types

Table 1 Demographic and drug use patterns by substitution group

0 = No current cannabis use, 1 = Less, 2 = No impact/same, 3 = More		**Alcohol** ***n*** **= 11,089**				**Tobacco** ***n*** **= 8,949**				**Methamphetamine** ***n*** **= 1,388**				**MDMA** ***n*** **= 5,832**				**LSD** ***n*** **= 4,827**			
		0	**1**	**2**	**3**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**
Age	16–20	32.3	33.3	34.5	45.1	25	35.3	33.1	42.6	4.6	17.3	9.7	15.7	28	45.4	36.1	59	19.4	43.1	33.9	56.3
	21–25	20.9	28.2	26.8	24.5	20	30.7	28.2	30	16.8	20.2	16.1	20.5	34.1	30.6	31.9	27.5	36	31.3	34	28.2
	26–35	18.3	22	19.4	13.4	23	20.1	20.1	17.5	35.3	29.3	31.2	33.7	24.5	15.5	19.3	9	27.7	16.3	20.5	12.2
	36+	28.5	16.6	19.4	17	32.1	14	18.7	9.8	43.4	33.3	42.9	30.1	13.4	8.4	12.7	4.5	16.9	9.3	11.6	3.4
Sex	Female	23.1	18.7	19.7	19.9	48.4	36.2	38.3	33.8	46.2	37.9	35.5	32.5	46.3	37.6	39.5	46.5	29.2	32.3	29.2	19.3
	Diverse	0.5	1.1	0.8	2.6	1	1.3	1.3	1.5	1.2	1.3	1.8	10.8	0.5	1	1.1	3	2.8	1.1	1.7	2.1
	Male	76.3	80.3	79.6	77.5	50.7	62.5	60.5	64.7	52.6	60.8	62.7	56.3	53.2	61.4	59.4	50.5	68	66.6	69.1	78.6
Ethnicity	Māori	12.8	17.1	14.7	20.6	20.5	20.8	18.1	17.7	20.8	28.6	21..0	24.1	12.9	20.9	14.1	24.5	14.8	19.4	13.9	13.5
	NZ Euro	76.3	73.8	75.8	66.3	66.4	68	72.7	72.7	75.7	63.2	71.7	61.5	80.1	68.5	76.9	65.5	78.2	71.1	76.6	76.4
	Other	10.9	9.1	9.5	13.1	13.1	11.1	9.2	9.7	3.5	8.2	7.3	14.5	7.1	10.7	9.1	10	7.1	9.6	9.5	10.1
Employ	Employed	65	67.9	65.3	62.8	63.5	64.1	62.5	58.7	73.8	65.3	68.2	49.4	71.9	63.3	64.4	60	80.3	68.9	68.4	61.6
	Student	26	23.2	26.2	25.2	20.7	23.9	26	29.4	2.9	7.8	6.7	7.2	24.1	28	29	31	15.4	23.3	24.5	31.7
	Unemployed	9	8.9	8.5	12.1	15.9	12	11.5	11.9	23.3	26.9	25.1	43.4	4.1	8.8	6.7	9	4.3	7.9	7	6.8
Education	High	61.5	61	59.1	52.9	60.1	57.4	58.8	56.4	63	54.7	57.1	50	70.4	56.6	62.2	47.5	72.8	57.3	61.6	56.7
	Low	38.5	39	40.9	47.1	39.9	42.6	41.3	43.6	37	45.3	42.9	59	29.6	43.4	37.9	52.5	27.2	42.7	38.4	43.3
Community	City	62.1	65.3	65.7	59.8	59.2	64.1	66.6	68.2	65.3	51.8	61.2	54.2	73.1	65.2	70	64.5	76	64.5	70	62.6
	Town/Rural	37.9	34.7	34.3	40.2	40.9	36	33.4	31.8	34.7	48.2	38.8	45.8	26.9	34.9	30	35.5	24	35.5	30	37.4
Other drug consumption	Daily	15.8	17	20.2	32	14.5	16.8	15.6	16	21.4	25.1	26.8	38.6	12.6	13.7	15.6	23.5	0.6	0.1	0.2	2.5
	Weekly	45.9	51.8	55.1	50	39.3	47.1	51	51	28.9	38.5	39.6	26.5	56.4	54.6	56.4	49.5	3.1	2	2.3	11.3
	Monthly	23.3	20.4	15.7	12.8	19.8	19.5	17.6	19.5	16.8	14.3	12.3	8.4	20.5	20.5	19.2	17.5	14.2	13.8	19.1	37
	Once/twice	15.1	10.7	9	5.2	17.1	12.4	11.6	10.6	16.8	14.3	11.7	12.1	7.6	9.2	7	7.5	82.1	84.1	78.4	49.2
	Mean days of use	38.5	42	46.8	58.7	76.7	68	69.7	77.9	43.1	21.8	28.4	62.6	6	6.9	7.3	23.6	4	3	3.5	10.4
	Typical quantity (mean)	16.4	21.9	23	28.5	7.7	6	6.8	6.4	3.4	2.5	2.4	5	1.7	1.8	1.8	3	1.2	1.3	1.2	1.6
Cannabis consumption	Daily	n/a	44.5	27	38.2	n/a	46.6	37.6	51.3	n/a	56.2	46.9	61.5	n/a	41.8	32.8	40	n/a	45	45	51.3
	Weekly	n/a	21.7	16.7	19.7	n/a	20.1	17.3	20.1	n/a	17.7	17.5	7.2	n/a	19.3	17.7	13.5	n/a	20.4	20.2	20.6
	Monthly	n/a	15.5	19	17.4	n/a	14.9	17	14.3	n/a	11.8	11.9	12.1	n/a	17.6	19.1	21	n/a	15.8	16.5	11.3
	Once/twice	n/a	18.3	37.3	24.7	n/a	18.4	28.1	14.3	n/a	14.3	23.7	19.3	n/a	21.4	30.4	25.5	n/a	18.7	18.3	16.8
	Mean days of use	n/a	63.1	40.6	54.9	n/a	64.9	53.3	70.5	n/a	75.3	64.2	77.6	n/a	59	47.9	54.9	n/a	63.2	63.1	70.5
	Typical joints (mean)	n/a	1	0.8	1.7	n/a	1.2	0.9	1.3	n/a	1.5	1.2	2.5	n/a	1.1	0.7	1.8	n/a	1.1	0.9	1.4

use and "no impact" on other drug, 3=cannabis use and "more" other drug). We did not have sufficient sample numbers to reliably examine the demographic characteristics of those who used cannabis with morphine and synthetic cannabinoids.

The frequency of use and amount used of each of the five other drug type is broadly consistent with the reported direction of cannabis co-use category. For example, the mean number of days of alcohol consumption in the past six months increased linearly with the reported co-use relationship (i.e., "less" alcohol=42.0 days, "no impact" on alcohol=46.8 days, "more" alcohol=58.7 days). Similarly, the mean number of standard alcohol drinks consumed on a typical occasion increased with the co-use category (i.e., "less" alcohol=21.9 drinks, "no impact" on alcohol=23.0 drinks, "more" alcohol=28.5 drinks). Interestingly, those alcohol drinkers who did not use cannabis reported lower frequency of alcohol use (i.e., 38.5 days) and typical number of standards drinks consumed (16.4 drinks) than any of the cannabis and alcohol co-use groups, likely reflecting a range of demographic factors that predict lower alcohol consumption, such as older age. These factors are controlled for in the multi-variable models in the next section.

Demographic and drug use predictors of cannabis and other substance use co-use categories

Table 2 presents the findings from the multi-variable generalised logistic regression model using demographic and drug use patterns to predict belonging to the "less" or "more" co-use groups respectively with the "no impact" group assigned as the reference.

All cannabis and alcohol co-users under 36 years old were more likely to report their use of cannabis resulted in "less" drinking compared to having "no impact". Those aged 16–20 were also more likely to report their use of cannabis resulted in "more" drinking (OR=2.07) compared to "no impact". Males (OR=1.14) and Māori (OR=1.19) were more likely to report their cannabis use resulted in "less" drinking. Students were less likely to report their use of cannabis resulted in "less" drinking (OR=0.83). Those who reported their cannabis use led to "less" drinking were less likely to report daily (OR=0.72) or weekly (OR=0.82) alcohol use, and less likely to consume a higher number of standard alcoholic drinks on a typical occasion (OR=0.83). Those who reported their cannabis use led to "more" alcohol use were more likely to report daily drinking (OR=3.25) and drinking a higher number of drinks on a typical occasion (OR=1.43). Those alcohol drinkers who did not use cannabis in the previous six months were less likely to report daily (OR=0.51) or weekly (OR=0.64) drinking, and less likely to report a higher number of drinks consumed on a typical occasion (OR=0.28).

For cannabis and tobacco co-users, there was a polarisation effect with all age groups under 36 years both more likely to report cannabis use resulted in "more" and "less" tobacco use compared to cannabis having "no impact". Males were more likely to report their cannabis use resulted in "more" tobacco use (OR=1.20) and less like to report using tobacco and no cannabis (OR=0.70). Māori (OR=1.25) were more likely to report their cannabis use resulted in "less" tobacco use. Students (OR=0.80) and those living in cities (OR=0.88) were less likely to report cannabis use led to "less" tobacco smoking. Those who reported cannabis use led to using "less" tobacco use smoked fewer cigarettes per day (OR=0.98) and were more likely to smoke tobacco weekly (OR=1.23). Those who reported their cannabis use led to "more" tobacco use were more likely to report daily (OR=2.76), weekly (OR=2.82) or monthly (OR=1.75) tobacco smoking.

For co-users of cannabis and methamphetamine, 16–20-year-olds (OR=2.35) and 21–25-year-olds (OR=1.66) were more likely to report their cannabis use resulted in using "less" methamphetamine. Those aged 16–20 years were also more likely to report cannabis use led to using "more" methamphetamine (OR=2.62). Māori were more likely to report cannabis use resulted in "less" methamphetamine use (OR=1.51). Those living in cities were less likely to report cannabis use resulted in "less" methamphetamine use (OR=0.70). Those who reported their cannabis use led to "less" methamphetamine use were less likely to report daily methamphetamine use (OR=0.57). Those who reported using cannabis led them to use "more" methamphetamine were more likely to report daily (OR=4.61) or weekly (OR=2.46) use, and to report using a higher number of methamphetamine "points" on a typical occasion (OR=1.15). Methamphetamine users who had not used cannabis in the past six months were more likely to report daily methamphetamine use (OR=1.65) and to report using a higher number of methamphetamine points on a typical occasion (OR=1.11).

For cannabis and MDMA co-use, there was again a polarisation among young adults. Those aged 16–20 years were both more likely to report cannabis use resulted in "less" MDMA use (OR=2.44) and "more" MDMA use (OR=3.49) compared to having "no impact". Those aged 21–25 years were more likely to report cannabis use resulted in "less" MDMA use (OR=1.74). Males were less likely to report that cannabis use led to "more" MDMA use (OR=0.70). Māori were more likely to report their cannabis use resulted in both "less" (OR=1.64) and "more" (OR=1.74) MDMA use compared to "no impact". Unemployed respondents were more likely to report their cannabis use resulted in "less" MDMA use (OR=1.36). Students (OR=0.77) and those living in cities (OR=0.86) were less likely to report cannabis use resulted in "less"

use of MDMA. Those who reported their cannabis use led to "less" MDMA use were less likely to report daily/weekly (OR=0.76) or monthly (OR=0.76) MDMA use. Those who reported their cannabis use led to "more" MDMA use were more likely to report daily/weekly (OR=4.14) or monthly (OR=2.25) MDMA use and using a higher number of MDMA pills on a typical occasion (OR=1.27).

For co-users of cannabis and LSD, results were again polarised by young adult age cohort. Cannabis and LSD users aged 16–20-year-olds (OR=2.84) and 21–25-year-olds (OR=1.64) were more likely to report cannabis use resulting in "more" LSD use compared to "no impact". Those aged 16–20-year-olds (OR=1.78) and 21–25-year-olds (OR=1.24) were also more likely to report cannabis resulting in "less" LSD use compared to "no impact". Males were more likely to report their cannabis use resulted in "more" LSD use (OR=1.57). Māori were more likely to report their cannabis use resulted in "less" LSD use (OR=1.45). Students (OR=0.76) and those living in cities (OR=0.81) were less likely to report their cannabis use resulted in "less" LSD use. Those who reported using "less" LSD were less likely to report daily/weekly/monthly LSD use (OR=0.62) compared to 1–2 times in the past six months. Those who reported using "more" LSD were more likely to report higher numbers of LSD tabs used on a typical occasion (OR=1.28) and to report daily/weekly/monthly LSD use (OR=3.04) compared to 1–2 times in the past six months.

Discussion

This study found distinct differences in cannabis and alcohol and other drug co-use patterns between different population subgroups (e.g., age, ethnicity, occupation, urbanicity) and for different drug types among a very large convenience sample of people who use cannabis. A strength of our study, in addition to the very large sample size of people who use cannabis, is we used a custom designed question that specifically referred to the causal influence of cannabis use on the level of use of other drug types. Many policy studies of cannabis co-use have only reported statistical associations between cannabis use and other drug use patterns following a policy change. Our study is also a rare example of cannabis and other drug co-use outside of North America.

For cannabis and alcohol co-users, 60% reported using cannabis led to "less" alcohol consumption (37% "no impact"), and this "less" group reported lower frequency of drinking and number of standard drinks consumed on a typical occasion after controlling for a range of demographic characteristics associated high higher alcohol consumption (e.g., age and gender). Calvert and Erickson [35] found that monthly purchases of alcohol (specifically wine) declined in Colorado and Washington state after the legalization of recreational cannabis, while purchases of spirits increased in Washington state but decreased in Oregon after cannabis legalization [35]. Mital et al. [34] found Canada-wide monthly beer sales dropped after cannabis legalization, but there was no change in spirits sales. In contrast, other studies of U.S. legalisation states found cannabis legalization resulted in no change in alcohol purchase and use [34]. The substitution of legal cannabis for alcohol may reflect the similar neurological effects of each substance [17], similar social acceptability among young people, and comparable price. Studies of college students have found some were motivated to use cannabis as a mean to reduce their alcohol consumption and related negative outcomes [19]. It is important to note that while young adults, males and Māori in our study were all more likely to report cannabis leading to "less" alcohol use, all these groups have higher baseline rates of hazardous drinking in New Zealand [42]. In addition, all those who used cannabis and alcohol, including those who reported cannabis use resulted in "less" drinking, reported higher alcohol consumption than alcohol drinkers who did not use cannabis. This suggests that those who use alcohol but not cannabis may have personality or social influences that limit alcohol consumption that are not explained in our models, such as enhanced impulse control, family and work commitments, social conservatism, or religiosity [26].

For cannabis and tobacco co-users, around one in five reported cannabis use led to "more" tobacco use (the highest "more" use of the other drugs), and this "more" group were more likely to smoke tobacco daily. Conversely, the one-third of the cannabis and tobacco co-users who reported using "less" tobacco, smoked slightly fewer cigarettes and were less like to be daily tobacco smokers. Studies have highlighted the risk of cannabis and tobacco co-use trajectories including how the effects of one reportedly triggers and/or enhances the effects of the other [e.g., 43]. This is likely to be particularly the case in countries where cannabis is typically combined with tobacco in the same roll-your-own cigarette. Cannabis is not typically combined with tobacco in this way in New Zealand, yet cannabis and tobacco use share the same mode of administration (i.e., smoking), administration equipment (i.e., lighters and roll-your-own papers) and often the same semi-public consumption locations (i.e., away from designated smoke free areas which include bars and restaurants in New Zealand). This shared social context of use may facilitate complementary use. In addition, the rapid growth in the use of vaping devices among youth, which can be used to consume both nicotine and cannabis, may further reinforce the complementary social context of use [44].

For cannabis and methamphetamine co-users, 40% reported cannabis use resulted in "less"

Table 2 Predictors of substitution group by demographic and drug use patterns

0 = No current cannabis use, 1 = Less, 2 = No impact/same (reference), 3 = More		Alcohol *n* = 10,952				Tobacco *n* = 8,808				Methamphetamine *n* = 1,353				MDMA *n* = 5,751				LSD *n* = 4,737			
Variable	**Outcome**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**
Age: 16–20 vs 36+	0	-0.26	0.0055	0.77	0.64, 0.93	-0.78	< .0001	0.46	0.35, 0.59	-0.67	0.1216	0.51	0.22, 1.19	-0.07	0.6467	0.93	0.69, 1.27	-0.69	< .0001	0.5	0.36, 0.71
Age: 16–20 vs 36+	1	0.22	0.0035	1.24	1.08, 1.44	0.41	< .0001	1.5	1.26, 1.78	0.85	< .0001	2.35	1.56, 3.53	0.89	< .0001	2.44	1.91, 3.13	0.58	< .0001	1.78	1.46, 2.16
Age: 16–20 vs 36+	3	0.73	0.0002	2.07	1.41, 3.04	0.98	< .0001	2.67	2.16, 3.28	0.96	0.0242	2.62	1.13, 6.07	1.25	0.0028	3.49	1.54, 7.93	1.04	< .0001	2.84	1.89, 4.28
Age: 21–25 vs 36+	0	-0.5	< .0001	0.6	0.51, 0.72	-0.81	< .0001	0.45	0.35, 0.57	0.09	0.7251	1.1	0.66, 1.83	0.1	0.4493	1.11	0.85, 1.45	-0.2	0.1436	0.82	0.63, 1.07
Age: 21–25 vs 36+	1	0.25	0.0004	1.28	1.12, 1.48	0.38	< .0001	1.46	1.24, 1.73	0.51	0.0048	1.66	1.17, 2.36	0.55	< .0001	1.74	1.38, 2.20	0.22	0.0254	1.24	1.03, 1.51
Age: 21–25 vs 36+	3	0.23	0.2445	1.26	0.85, 1.87	0.79	< .0001	2.2	1.78, 2.70	0.37	0.3513	1.44	0.67, 3.12	0.74	0.0765	2.09	0.92, 4.74	0.49	0.0226	1.64	1.07, 2.51
Age: 26–35 vs 36+	0	-0.41	< .0001	0.66	0.55, 0.79	-0.37	0.0019	0.69	0.55, 0.87	0.04	0.8551	1.04	0.70, 1.54	0.21	0.1374	1.23	0.94, 1.62				
Age: 26–35 vs 36+	1	0.3	< .0001	1.35	1.17, 1.55	0.27	0.0023	1.31	1.10, 1.56	0.22	0.1484	1.25	0.93, 1.68	0.25	0.0552	1.28	1.00, 1.64				
Age: 26–35 vs 36+	3	-0.16	0.4628	0.85	0.55, 1.32	0.52	< .0001	1.67	1.35, 2.08	0.48	0.1223	1.62	0.88, 3.00	0.35	0.4384	1.42	0.58, 3.49				
Male vs Female	0	0.06	0.4101	1.06	0.92, 1.23	-0.35	< .0001	0.7	0.60, 0.83	-0.49	0.0074	0.61	0.43, 0.88	-0.34	< .0001	0.71	0.60, 0.84	-0.07	0.6164	0.94	0.73, 1.21
Male vs Female	1	0.13	0.0204	1.14	1.02, 1.28	0.09	0.1033	1.09	0.98, 1.21	-0.09	0.5093	0.92	0.71, 1.19	0.12	0.0716	1.13	0.99, 1.28	-0.12	0.1226	0.88	0.76, 1.03
Male vs Female	3	-0.13	0.423	0.88	0.65, 1.20	0.18	0.0028	1.2	1.07, 1.36	0.18	0.5133	1.2	0.70, 2.06	-0.36	0.021	0.7	0.51, 0.95	0.45	0.0096	1.57	1.12, 2.20
Ethnicity: Māori vs NZ Euro	0	-0.02	0.7836	0.98	0.82, 1.16	0.09	0.4095	1.09	0.89, 1.35	-0.25	0.2698	0.78	0.50, 1.21	-0.12	0.3224	0.89	0.70, 1.13	0.004	0.9794	1	0.72, 1.41
Ethnicity: Māori vs NZ Euro	1	0.17	0.0062	1.19	1.05, 1.35	0.22	0.0008	1.25	1.10, 1.43	0.41	0.0049	1.51	1.13, 2.02	0.49	< .0001	1.64	1.39, 1.93	0.37	0.0001	1.45	1.20, 1.76
Ethnicity: Māori vs NZ Euro	3	0.3	0.0725	1.34	0.97, 1.85	-0.04	0.5801	0.96	0.82, 1.12	-0.17	0.6063	0.85	0.45, 1.59	0.55	0.0028	1.74	1.21, 2.50	-0.21	0.3222	0.81	0.54, 1.23
Ethnicity: Other vs NZ Euro	0	0.02	0.8564	1.02	0.84, 1.24	0.51	< .0001	1.67	1.30, 2.15	-0.66	0.1483	0.52	0.21, 1.26	-0.28	0.0695	0.75	0.56, 1.02	-0.27	0.2438	0.77	0.49, 1.20

Table 2 (continued)

0 = No current cannabis use, 1 = Less, 2 = No impact/same (reference), 3 = More		Alcohol *n* = 10,952				Tobacco *n* = 8,808				Methamphetamine *n* = 1,353				MDMA *n* = 5,751				LSD *n* = 4,737			
Variable	**Outcome**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**
Ethnicity: Other vs NZ Euro	1	-0.03	0.6633	0.97	0.83, 1.13	0.24	0.0052	1.27	1.08, 1.51	0.16	0.5127	1.17	0.73, 1.90	0.29	0.0068	1.33	1.08, 1.64	0.12	0.3607	1.12	0.88, 1.45
Ethnicity: Other vs NZ Euro	3	0.54	0.0039	1.72	1.19, 2.48	0.01	0.9176	1.01	0.83, 1.23	0.3	0.4839	1.36	0.58, 3.18	0.06	0.8355	1.06	0.62, 1.80	0.02	0.9357	1.02	0.64, 1.63
Student vs Employed	0	0.12	0.1243	1.13	0.97, 1.33	0.03	0.7993	1.03	0.81, 1.31	-1.16	0.0364	0.31	0.11, 0.93	-0.23	0.0428	0.8	0.64, 0.99	-0.39	0.031	0.68	0.48, 0.97
Student vs Employed	1	-0.19	0.0019	0.83	0.74, 0.93	-0.23	0.0011	0.8	0.70, 0.91	-0.16	0.5487	0.86	0.51, 1.42	-0.27	0.0012	0.77	0.65, 0.90	-0.27	0.0055	0.76	0.63, 0.92
Student vs Employed	3	-0.32	0.0439	0.73	0.53, 0.99	0.06	0.4125	1.06	0.92, 1.24	0.23	0.6631	1.26	0.45, 3.49	-0.19	0.3098	0.83	0.58, 1.19	0.19	0.2725	1.2	0.87, 1.67
Unemployed vs Employed	0	-0.13	0.2446	0.88	0.71, 1.09	0.12	0.3217	1.13	0.89, 1.43	-0.41	0.0618	0.67	0.43, 1.02	-0.58	0.0038	0.56	0.38, 0.83	-0.54	0.0599	0.58	0.33, 1.02
Unemployed vs Employed	1	-0.0003	0.9968	1	0.85, 1.18	0.1	0.2216	1.11	0.94, 1.31	0.14	0.3675	1.15	0.85, 1.54	0.3	0.0124	1.36	1.07, 1.72	0.09	0.5442	1.09	0.82, 1.45
Unemployed vs Employed	3	0.34	0.0958	1.4	0.94, 2.09	0.16	0.095	1.18	0.97, 1.42	0.52	0.0663	1.68	0.97, 2.94	0.21	0.4976	1.23	0.68, 2.22	0.005	0.9874	1.01	0.57, 1.77
Education: High vs Low	0		n.s.				n.s.				n.s.			0.23	0.0159	1.26	1.04, 1.52		n.s.		
Education: High vs Low	1		n.s.				n.s.				n.s.			-0.01	0.8896	0.99	0.86, 1.14		n.s.		
Education: High vs Low	3		n.s.				n.s.				n.s.			-0.15	0.3553	0.86	0.62, 1.19		n.s.		
City vs Rural/small town	0		n.s.			-0.24	0.0067	0.79	0.67, 0.94	0.23	0.2103	1.26	0.88, 1.81	0.14	0.1202	1.16	0.96, 1.39	0.31	0.0275	1.36	1.03, 1.78
City vs Rural/small town	1		n.s.			-0.13	0.0217	0.88	0.79, 0.98	-0.36	0.0043	0.7	0.55, 0.89	-0.16	0.0227	0.86	0.75, 0.98	-0.21	0.0086	0.81	0.70, 0.95

Table 2 (continued)

0 = No current cannabis use, 1 = Less, 2 = No impact/same (reference), 3 = More		Alcohol *n* = 10,952				Tobacco *n* = 8,808				Methamphetamine *n* = 1,353				MDMA *n* = 5,751				LSD *n* = 4,737			
Variable	**Outcome**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**	**Estimate**	***p*-value**	**OR**	**OR 95% CI**
City vs Rural/small town	3		n.s.			0.08	0.1959	1.09	0.96, 1.23	-0.37	0.1521	0.69	0.42, 1.15	-0.05	0.7632	0.95	0.69, 1.32	-0.24	0.1088	0.79	0.59, 1.05
Drug quantity used	0	-1.26	< .0001	0.28	0.24, 0.33	-0.003	0.6373	1	0.98, 1.01	0.11	0.0002	1.11	1.05, 1.18	0.0001	0.9979	1	0.93, 1.07	-0.03	0.6988	0.97	0.82, 1.14
Drug quantity used	1	-0.18	0.0024	0.83	0.74, 0.94	-0.02	0.0006	0.98	0.98, 0.99	0.02	0.3918	1.02	0.97, 1.08	0.01	0.8175	1.01	0.96, 1.06	0.06	0.2051	1.06	0.97, 1.17
Drug quantity used	3	0.36	0.0271	1.43	1.04, 1.97	-0.01	0.0126	0.99	0.98, 1.00	0.14	< .0001	1.15	1.08, 1.23	0.24	< .0001	1.27	1.18, 1.36	0.25	< .0001	1.28	1.14, 1.44
Daily vs Once or twice 6m	0	-0.67	< .0001	0.51	0.41, 0.64	-0.15	0.2019	0.86	0.68, 1.09	0.5	0.0421	1.65	1.02, 2.66	-0.34	0.0329	0.71	0.53, 0.97	-0.14	0.3688	0.87	0.64, 1.18
Daily vs Once or twice 6m	1	-0.32	0.0003	0.72	0.61, 0.86	0.12	0.1188	1.13	0.97, 1.31	-0.57	0.0055	0.57	0.38, 0.85	-0.28	0.0133	0.76	0.61, 0.94	-0.48	< .0001	0.62	0.51, 0.76
Daily vs Once or twice 6m	3	1.18	< .0001	3.25	1.84, 5.75	1.01	< .0001	2.76	2.28, 3.33	1.53	< .0001	4.61	2.27, 9.37	1.42	< .0001	4.14	2.70, 6.34	1.11	< .0001	3.04	2.29, 4.04
Weekly vs Once/twice 6m	0	-0.44	< .0001	0.64	0.53, 0.78	-0.54	0.001	0.58	0.42, 0.80	0.38	0.1079	1.46	0.92, 2.30								
Weekly vs Once/twice 6m	1	-0.2	0.0111	0.82	0.70, 0.96	0.21	0.0191	1.23	1.04, 1.47	-0.19	0.2641	0.83	0.59, 1.16								
Weekly vs Once/twice 6m	3	0.49	0.0835	1.63	0.94, 2.83	1.04	< .0001	2.82	2.29, 3.48	0.9	0.0199	2.46	1.15, 5.26								
Monthly vs Once/twice 6m	0	0.08	0.4673	1.08	0.88, 1.34	-0.4	0.015	0.67	0.49, 0.93	-0.2	0.4768	0.82	0.48, 1.41	-0.24	0.0095	0.78	0.65, 0.94				
Monthly vs Once/twice 6m	1	0.12	0.1906	1.13	0.94, 1.35	0.15	0.1041	1.16	0.97, 1.38	-0.22	0.1924	0.8	0.57, 1.12	-0.27	0.0002	0.76	0.66, 0.88				
Monthly vs Once/twice 6m	3	0.35	0.2642	1.42	0.77, 2.64	0.56	< .0001	1.75	1.40, 2.18	0.58	0.1724	1.78	0.78, 4.08	0.81	< .0001	2.25	1.54, 3.30				

Table 2 (continued)

0 = No current cannabis use, 1 = Less, 2 = No impact/same (reference), 3 = More		Alcohol $n = 10,952$				Tobacco $n = 8,808$				Methamphetamine $n = 1,353$				MDMA $n = 5,751$				LSD $n = 4,737$			
Variable	Outcome	Estimate	*p*-value	OR	OR 95% CI	Estimate	*p*-value	OR	OR 95% CI	Estimate	*p*-value	OR	OR 95% CI	Estimate	*p*-value	OR	OR 95% CI	Estimate	*p*-value	OR	OR 95% CI
P-value Hosmer and Lemeshow Goodness-of-fit test		0.0559				0.1384				0.7728				0.9589				0.3562			

methamphetamine use (53% "no impact"), and this group reported using methamphetamine approximately half of the frequency of those who did not use cannabis, and one-third of the frequency of those using cannabis and reported using "more" methamphetamine. In these cases, cannabis may help suppress cravings for methamphetamine while also offering fewer negative side effects and withdrawal impacts. Studies of motivations for the substitution of substances have identified managing adverse effects and withdrawal symptoms as an important motivation for substitution toward drug types with more moderate side effects [11, 13, 45].

For cannabis and MDMA co-users, almost seven out-of-ten reported cannabis had "no impact" on their level of MDMA use. Around a quarter reported cannabis use lead to less MDMA use but the "less" group had similar MDMA consumption patterns to those who did not use cannabis and the "no impact" group. This lack of impact of cannabis use on MDMA use may reflect differences in the neurological effects, social context, and availability of the two drugs. MDMA has stimulant and hallucinogenic proprieties that provide energy and mild psychedelic experiences, typically used to enhance stamina for, and the experience of, all night dancing. In contrast, cannabis has depressant effects that facilitate introspection, relaxation, and sociability. As outlined earlier, MDMA is less available in New Zealand with a much higher price compared to Europe and the U.S., reflecting New Zealand's geographical distance from central MDMA manufacture hubs in Europe [4, 5]. In contrast, there is large scale illegal cultivation of cannabis in New Zealand with domestic cultivation entirely meeting local demand, and hence cannabis is widely available at a relatively low price [4, 5].

Similarly, cocaine has a very low availability and high price in New Zealand compared to many countries, and this likely to put significant practical and financial constraints on the potential for any substitution between cannabis and cocaine [4, 5]. For cannabis and LSD co-use, we also found little evidence of substitution or complementary impact. Again, this may largely reflect qualitative differences in cannabis and LSD psychoactive experiences (i.e., mild euphoria vs. immersive psychedelic experience).

We did not have enough cannabis and synthetic cannabinoid co-users to include them in the logistic regression models. The reported descriptive co-use relationships between cannabis and synthetic cannabinoids suggests substitution. A number of studies, including our own, have suggested synthetic cannabinoids are substitutes for natural cannabis in contexts where the supply and/or ability to use natural cannabis is difficult, for example prisons, workplaces and drug treatment facilitates where there is routine drug testing or close surveillance for signs of drug use, such as smell [10, 46, 47].

We found important demographic differences in co-use relationships between cannabis and other drugs. Māori (the indigenous people of Aotearoa New Zealand) were more likely to report that their cannabis use resulted in "less" alcohol, tobacco, methamphetamine, MDMA, and LSD use. This suggests that Māori may be more likely to consider cannabis to be the preferred substitute for many other drug types. This may reflect a more positive cultural perception of cannabis among Māori and other colonised indigenous and ethnic groups (e.g., Jamaicans) as an anti-establishment drug compared to alcohol and tobacco which have been historically associated with colonialisation and exploitation [48]. It may also reflect Māori cultural beliefs in the medicinal and spiritual properties of cannabis, again drawing on the beliefs found among Jamaican Rastafarian culture, which was influential among Māori in the 1970s and 1980s.

In contrast, students were less likely to report cannabis use resulted in lower levels of alcohol, tobacco, methamphetamine, MDMA, and LSD use. This may reflect aspects of the student lifestyle that facilitate greater substance use and experimentation, such as teenage rites of passage, greater leisure time, unstructured days, as well as anxiety and coping related to study performance, conformity pressure, and social living arrangements with other novelty seeking peers [19, 49]. Recent studies of college students have suggested complementary alcohol and cannabis co-use [50, 51], while others have reported harm minimisation motivations for cannabis use to reduce alcohol consumption and related negative consequences [19]. One study found the likelihood of simultaneous cannabis and alcohol use was higher among college students not living with their parents, consistent with influence of new freedoms and social living [52]. Curiosity and experimentation have been identified as leading reasons for both drug substitution and complementary drug use [45, 49].

Those living in cities were also less likely to report cannabis use resulted in lower levels of methamphetamine, MDMA and LSD use. This may reflect the easier availability of a greater range of drug types in cities and more networked drug markets compared to small towns and rural regions. Recent studies of drug availability in New Zealand have illustrated the lower availability of drugs like MDMA and cocaine in rural regions [4]. Studies have documented how shortages in the supply of a preferred drug are a motivation for using a substitute one, for example shortages of heroin leading to increased use of fentanyl [45, 53]. Conversely, high availability of other drugs may create a greater propensity to combine them with cannabis and alcohol, essentially reducing the practical need for substitution behaviour [19].

The impact of age on co-use behaviour was mixed, with adolescent age cohorts (aged 16–20 years) both more likely to report cannabis use resulting in "more" and "less" other substance use compared to having "no impact", while young adults were more likely to report cannabis use resulting in lower levels of other drug use. This mixed impact is consistent with studies of the impact of cannabis liberalisation on alcohol consumption by adolescents which found both increased and lower alcohol consumption [54] and prior studies of adolescents which found both complementary and substitution of alcohol and cannabis [50]. In contrast, young adults in our study (aged 21-25years) were more likely to say cannabis use resulted in lower use of alcohol, methamphetamine, and MDMA. A study of U.S. college students found that following cannabis legalisation there was a reduction in binge alcohol drinking among students aged 21 or older but not among younger students [55]. As noted above, other studies of U.S. college students have found no impact of cannabis legalization on other drug use [56]. Our mixed findings may reflect different life stages and developmental trajectories. The youth age cohort (16–20 years) is a time of transition from adolescence to young adulthood and is associated with risk-taking and novelty seeking and has been identified as a period of high risk of developing substance co-use [23, 43]. The next older cohort (21–35 years) has greater neurological development and often accumulated real world experience of alcohol and other drug use, including related negative consequences of poly drug use, and hence may be more likely to consider harm reduction behaviour, such as favouring substances with fewer side effects and less harmful consequences. A recent review of the literature has highlighted that there may be an age dependant decline in cannabis and alcohol interactions, suggesting that older age may moderate the level of substitution and complementarity behaviour [26].

Limitations

There are limitations with this study which should be considered when interpreting the findings. First, our sample of people who use cannabis is taken from an online convenience survey of drug trends and hence may not be representative of the wider group of people who use cannabis in the New Zealand population. It would be prohibitively costly and time consuming to collect a similarly large representative sample of people who frequently use cannabis [57]. It is also important to note that representative population surveys also currently face their own coverage and self-reporting issues, including the decline of household telephones and related sampling frames, and the reluctance to report illegal drug use in person due to legal risks and social stigma [57]. There is some evidence that self-administered online surveys are perceived by respondents to provide greater anonymity with respect to sensitive topics [58]. The strength of the NZDTS sample for the analysis in this paper is the very

large sample size that allowed robust analysis of substitution behaviour within key important demographic subgroups.

Second, the measures and descriptions of co-use relationships are based on self-reports with related fallibilities of recall, understanding, and social desirability bias. In terms of the validity of the self-reported co-use behaviour, the mean reported frequency of use and amount used on a typical occasion of other drug types, as reported by respondents in earlier sections of the survey, were broadly consistent with the reported direction of the co-use influence (i.e., "less", "same", "more").

Third, as explained earlier, only low proportions of the NZDTS sample had used morphine and heroin in the past six months, reflecting their low prevalence in New Zealand, and this prevented the investigation of cannabis and opiate substitution. The survey also did not collect detailed questions about prescription drug use. On the other hand, very few studies have investigated the co-use of cannabis with methamphetamine, MDMA, and LSD, as in our study.

Fourth, the NZDTS was principally designed to monitor drug market trends, and consequently, it does not include in-depth psychometric tests of respondents' personality traits and psychological disorders which recent research has suggested may be moderators of individual co-use decision making (e.g., sensation seeking, depression, substance use disorder) [25, 26, 29, 50]. In addition, the survey did not ask about the social context of use (e.g., social norms related to cannabis and alcohol, order of cannabis and alcohol use) and pharmacological formulation of cannabis (i.e., THC vs. CBD) which may also be moderating factors on individual co-use decision making [26, 29, 54].

Fifth, the survey questions asked about the use of cannabis and other drug types during the same six-month period and did not specify if this co-use involved simultaneous or concurrent use. This is an important distinction as simultaneous use of cannabis and other drugs has been found to increase intoxication and related harms compare to merely concurrent use [22, 25].

Sixth, our analysis is based on a single wave of cross-sectional survey data rather than longitudinal data following the same individuals over time to examine real-time day-to-day substitution behaviour. Instead, we made comparisons in substance use between population subgroups based on self-reported co-use dynamic over an entire six-month period. While the resulting self-categorisation of co-use causal relationship was consistent with earlier reporting of other drug use patterns over the same period, it does not provide a clear temporal sequence of cannabis and other drug use, for example, students report drinking less on days when they use cannabis before drinking alcohol [19, 59].

Seventh, the causal change question referred to broad relative change categories (i.e., "a lot more", "little more", "no impact/same", "little less", "a lot less"), no data was collected of the magnitude of these changes in drug consumption attributed to these causal categories. It is not clear whether respondents would be able to quantify these causal influences and express them in terms of changes in their substance use patterns.

Finally, the aim of the analysis was to explore cannabis and other drug co-use patterns among people who *currently* use cannabis, and consequently the findings concerning substitution/complementary behaviour may not be able to be easily extrapolated to the wider general population with less or no previous experience of cannabis use, for example in the case of assessing the case for cannabis legalisation.

Conclusion

Significant proportions of people who use cannabis in our survey reported that using cannabis led to lower levels of alcohol and methamphetamine use, and this substitution impact of cannabis was consistent with this group's lower consumption of these other drug types. Approximately seven-out-of-ten of cannabis co-users reported cannabis use had no impact on their level of LSD, MDMA, or cocaine use. While low proportions of respondents reported cannabis use led to "more" use of other drug types, one-in-five of co-users reported using cannabis resulted in more tobacco use.

Cannabis and other drug co-use relationships were different for Māori, students, adolescents, and those living in cities. This may reflect more positive cultural perspectives of cannabis, life stages and lifestyles that facilitate greater alcohol and other drug experimentation and consumption, and city environments where there is greater availability of a range of other drug types. Harm reduction theory of cannabis and alcohol and other drug substitution should take account of these moderating factors, as well as a range of personal and contextual influences identified in recent literature, including personality type, dependency disorders, the order of cannabis and alcohol use, and cannabinoid composition.

Our findings have a number of implications for harm reduction. Firstly, greater access to cannabis could provide opportunities for older young adults (20 years old+) to reduce excessive alcohol consumption within an age group with high prevalence of risky drinking. Cannabis may provide a lower risk option than heavy alcohol use among young adults who are in a particularly hedonistic phase of their lives. Secondly, greater access to cannabis could play a part in reducing methamphetamine use for some individuals, either as means to reduce the frequency of methamphetamine consumption, or as an adjunct to support treatment for methamphetamine related issues.

Several harm reduction studies have indicated the potential of medicinal cannabis to support reduction in the use of other drugs with have higher risk of side-effects, including stimulants and prescription opioid analgesics [11–14]. Cannabis may be particularly appropriate in this role for individuals who do not wish or unable to stop the use of other substances completely [33]. Medicinal cannabis schemes could be explicitly extended to include provisions for prescriptions for medicinal cannabis to reduce use of higher risks drugs, including excessive alcohol, stimulants and prescription analgesics. Our study suggests cultural groups with an existing positive cultural affinity for cannabis may be particularly engaged to use cannabis in this role to support lower risk drug use or treatment options. Harm reduction initiatives could include peer and community run programs offering free or low-cost cannabis to disadvantaged people experiencing substance use issues, as has been trialled in Vancouver [33]. In New Zealand, the Government's proposed Cannabis and Legalisation Control Bill (CLCB) included local retail cannabis licensing provisions to reflect community characteristics, and this included opportunities for Māori providers with culturally specific approaches to substance use and harm [8]. It could be argued, based on our results, that these provisions would not only provide Māori with the opportunity to enter the legal cannabis industry, but also provide enhanced access to legal cannabis to lower drinking and other drug use.

Acknowledgements
We would like to acknowledge everyone who responded to the New Zealand Drugs Trends Survey (NZDTS) without who this research would not be possible.

Author contributions
Chris Wilkins: Writing – original draft, Writing - review & editing, Conceptualization, Investigation. Jose Romeo: Formal analysis, Data curation, Conceptualization, Investigation. Marta Rychert: Writing – review & editing, Conceptualization, Investigation. Thomas Graydon-Guy: Methodology, Project administration, Conceptualization, Investigation.

Funding
Funding to support the completion of this research was provides by Health Research Council (HRC) of New Zealand (grant 23/244).

Data availability
The data that support the findings of this study are available from the SHORE & Whariki Research Centre, Massey University, but restrictions apply to the availability of these data, as they are involve sensitive topics and illegal behavior related to drug use and so are not publicly available. The data are, however, available from the authors upon reasonable request.

Declarations

Ethics approval and consent to participate
Ethics approval to conduct the New Zealand Drug Trends Survey which provided the data for this paper was obtained from the Massey University Human Subject Ethics Committee (Application code: SOA 17/43).

Consent for publication
All respondents of the New Zealand Drug Trends Survey were provided with a written participant information outlining the aims, objectives and procedures involved in the research and asked to consent to participate by ticking a box statement before beginning the survey (as outlined and approved by the university ethics committee).

Competing interests
The authors declare no competing interests.

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Received: 18 July 2024 / Accepted: 19 October 2024
Published online: 05 November 2024

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