

Estimation of the proportion of population cannabis consumption in Australia that is accounted for by daily users using Monte Carlo Simulation

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ABSTRACT

Aim To estimate the proportion of cannabis consumed in Australia by daily cannabis users. **Design** Monte Carlo simulation using parameters estimated from nationally representative and repeated cross-sectional household surveys in 2007, 2010, 2013 and 2016. **Setting** Australia **Participants** Adult samples (mean age = 49.9; 55% females) from four National Drug Strategy Household Surveys ($n = 92\,243$). **Measurement** Frequency of cannabis use (daily/weekly/about once a month/every few months/once or twice a year). The weighted estimated prevalence of users in each of these frequency levels was multiplied by population size to estimate the total number of users. Quantity of cannabis use was measured as number of joints consumed. The consumption of those who reported using bongs was converted into joints based on the bong to joint ratio estimated from the survey data. We estimated the proportion of cannabis consumed by daily users by Monte Carlo simulation using parameters estimated from the household surveys. We conducted 10 000 simulation trials, and in each trial we [1] simulated the number of users at each consumption level (stratum) based on estimated prevalence and population size[2], for each simulated individual, we simulated the number of days of cannabis use in a year based on frequency data[3], for each consumption day, we simulated the quantity consumed [4] and lastly we calculated the total joints consumed at each consumption level and estimated the proportion of joints consumed by daily users out of the total consumption. **Findings** The prevalence of past-year cannabis use increased from 8.9% [95% confidence interval (CI) = 8.5–9.4] in 2007 to 10.5% (95% CI = 10.0–11.1) in 2016, 16% of whom were daily users. Between 2007 and 2016, daily users accounted for between 81.6 and 85.7% of all cannabis consumed. Weekly users accounted for an additional 12.1–15.9%. **Conclusion** Between 2007 and 2016, only one in six Australian cannabis users were daily users, but they accounted for more than 80% of the estimated cannabis consumed in Australia.

Keywords Cannabis consumption, daily user, Monte Carlo simulation, marijuana, joints, bongs.

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Submitted 22 August 2019; initial review completed 23 October 2019; final version accepted 20 November 2019

INTRODUCTION

In most high-income countries the minority of heavy alcohol consumers account for most of the consumption[1]. This fact has often been used to justify public health policies that seek to reduce population harm by taxing alcohol to make it more expensive and by restricting its availability[2].

It is tempting to assume that the pattern of consumption observed with alcohol will not apply to cannabis, because cannabis has a lower dependence risk than alcohol and many cannabis users only use intermittently[3]. We update an estimate of the proportion of total cannabis

consumption in Australia that is accounted for by daily cannabis users[4]. We improve upon the earlier estimate that used plausible guesses of how many cannabis joints were used each year by daily, weekly and less frequent cannabis users. The earlier study estimated that daily cannabis users accounted for two-thirds of total consumption (68%), with weekly users accounting for a further 28%.

We improved upon this earlier estimate by [1] accounting for sampling uncertainty in the size of joints and bongs (the two most common units of cannabis use in Australia) and [2] by replicating these estimates using data from four Australian household surveys of drug use.

METHOD

Design

We used Monte Carlo simulation methods to estimate the proportion of cannabis consumed by daily cannabis users in Australia[5]. We derived the parameters for the simulation from the National Drug Strategy Household Survey (NDSHS), a national cross-sectional survey that is conducted every 3 years to provide data on drug use in a nationally representative sample of the Australian adult population.

We used data from adults (aged 18 years or above; mean age = 49.9; 55% females; total $N = 92\,243$) from surveys in 2007, 2010, 2013 and 2016. More than 23 000 individuals participated in each survey. The data were weighted to align the sample with the Australian population. Detailed descriptions of the data collection procedures can be found elsewhere[6,7]. The simulation was performed using R version 3.5.3.

In each simulation trial, we simulated consumption in each cannabis user strata (daily/weekly/about once a month/every few months/once or twice a year) based on the following equation:

$$\sum_{i=1}^{N_j} \text{Number of days cannabis was consumed}_i \\ \times \text{Number of joints consumed each day}_i,$$

where N_j was the simulated number of users in strata j and the subscript i denotes the simulated data for individual i . The estimated proportion of cannabis consumed by daily user in each trial was then calculated by

$$\frac{\sum_{i=1}^{N_{\text{Daily users}}} \text{Number of days cannabis was consumed}_i \\ \times \text{Number of joints consumed each day}_i}{\sum_j \sum_{i=1}^{N_j} \text{Number of days cannabis was consumed}_i \\ \times \text{Number of joints consumed each day}_i}.$$

The final estimate was calculated by averaging across all simulation trials.

Modeling parameters

Number of daily and less frequent cannabis users The prevalence of five levels of cannabis use was estimated using the item: 'In the last 12 months, how often did you use marijuana/cannabis: every day/once a week or more/about once a month/every few months/once or twice a year? We multiplied the prevalence (and the standard deviation) by estimates of the size of the Australian population to estimate the number of cannabis users in each stratum.

Number of days of cannabis use Frequency of cannabis use was measured using an ordinal scale: 'daily', 'weekly',

'about once a month', 'every few months' and 'once or twice a year'. As the exact number of days on which cannabis was used was not measured, we assumed that number of days of cannabis use was a function of log-normal distribution within each of the five strata of use (see Supporting information Appendix 2 for the technical details concerning how the parameters of the log-normal distribution were determined).

Quantity of cannabis used per day We estimated how many joints each type of cannabis user used based on the item: 'On a day you use marijuana/cannabis, on average how many cones, bongs or joints do you normally have?' We used 'joint' as the unit of consumption and converted the number of bongs and cones to joints using a ratio of 3 to 1. This ratio was estimated based on the ratio of median consumption reported by those who used joints and bongs (see Supporting information Appendix Table S1 for details). We modelled uncertainty in the conversion rate by assuming that the number of bongs in a joint followed a normal distribution with a mean of 3 and standard deviation of 0.5. This meant that we assumed that 95% of joints contained between two and four bongs. After converting the number of bongs to joints, we estimated the mean quantity of cannabis consumed within each of the five types of user.

Simulation

We simulated 10 000 random trials for each stratum and in each trial we:

- drew the number of cannabis users within each stratum from a normal distribution because normal distribution is a good approximation for binomial distribution for large samples;
- for each simulated individual we simulated the number of days that cannabis was consumed and the number of joints consumed in a day from the log-normal distributions;
- multiplied the number of days and number of joints per day to calculate the total number joints consumed in a year for each individual; and
- we obtained an annual total by summing the total number of cannabis joints consumed by users in each stratum in a year.

The point estimate of total consumption was the mean of the 10 000 trials. The 95% credible interval comprised the 2.5 and 97.5% percentile of the 10 000 trials. We used the same procedure in each of the 4 survey years. The simulation was performed using R version 3.5.3.

RESULTS

Table 1 shows the estimated prevalence of each type of cannabis users (strata) by year. The estimated prevalence

Table 1 Simulation parameters estimated from the NDSHS 2007, 2010, 2013 and 2016.

	Prevalence		Number of days using cannabis				Number of joints used each day	
					Simulation parameters ^b		Simulation parameters ^d	
	%	95% CI ^a	Min. ^b	Max.	mu	sigma	mu	sigma
2016								
Daily	1.54	(1.33, 1.77)	313	365	1.99	0.66	1.07	0.83
Weekly	2.33	(2.08, 2.61)	52	312	2.78	0.93	0.33	0.74
About once a month	1.28	(1.11, 1.49)	12	51	1.84	0.61	0.08	0.68
Every few months	1.85	(1.63, 2.09)	3	11	1.10	0.37	0.08	0.77
Once or twice a year	3.53	(3.24, 3.85)	1	2	0.35	0.12	-0.18	0.77
Total	10.53	(10.02, 11.06)						
2013								
Daily	1.27	(1.1, 1.46)	313	365	1.99	0.66	1.02	0.78
Weekly	1.91	(1.7, 2.15)	52	312	2.78	0.93	0.35	0.86
About once a month	1.27	(1.09, 1.48)	12	51	1.84	0.61	0.00	0.77
Every few months	1.76	(1.55, 1.99)	3	11	1.10	0.37	-0.17	0.79
Once or twice a year	3.61	(3.32, 3.93)	1	2	0.35	0.12	-0.42	0.79
Total	9.82	(9.34, 10.33)						
2010								
Daily	1.41	(1.23, 1.61)	313	365	1.99	0.66	1.17	0.81
Weekly	2.19	(1.98, 2.42)	52	312	2.78	0.93	0.31	0.80
About once a month	1.30	(1.13, 1.5)	12	51	1.84	0.61	0.00	0.78
Every few months	1.77	(1.58, 1.99)	3	11	1.10	0.37	-0.09	0.76
Once or twice a year	3.37	(3.1, 3.67)	1	2	0.35	0.12	-0.38	0.81
Total	10.04	(9.59, 10.53)						
2007								
Daily	1.40	(1.21, 1.61)	313	365	1.99	0.66	1.10	0.82
Weekly	1.81	(1.59, 2.05)	52	312	2.78	0.93	0.31	0.83
About once a month	1.08	(0.92, 1.28)	12	51	1.84	0.61	0.13	0.78
Every few months	1.68	(1.46, 1.93)	3	11	1.10	0.37	-0.07	0.84
Once or twice a year	2.96	(2.69, 3.26)	1	2	0.35	0.12	-0.32	0.82
Total	8.93	(8.45, 9.44)						

^aThe 95% confidence interval (CI) was calculated based on normal approximation. ^bThe frequency of cannabis use was measured on a crude ordinal scale, so we set the minimum and maximum number of days of use for each stratum. In the simulation, the number of days for each simulated individual was simulated based on a log-normal distribution (see Supporting information Appendix for technical details). ^cThese are simulation parameters for log-normal distributions to generate the number of days using cannabis (see Supporting information Appendix). ^dThese are simulation parameters for log-normal distributions to generate the number of joints used each day (when cannabis was used), and were estimated from the National Drug Strategy Household Survey (NDSHS).

of past-year cannabis use increased from 8.93% (95% CI: [8.45 - 9.44]) in 2007 to 10.53% (95% CI: [10.02 - 11.06]) in 2016. This represented an increase in the estimated number of cannabis users from 1.45 to 1.95 million.

The estimated number of joints used in a day for each stratum were similar across the 4 survey years. Daily users (who comprised 16% of all users) reported the highest number. Table 2 shows the estimated total annual consumption by stratum by year.

In all four surveys, it was estimated that more than 81% of the cannabis was consumed by daily users. This proportion was lowest in 2013 (81.6%) and highest in 2007 (85.67%). Weekly cannabis users consumed approximately 14% of the total cannabis (lowest in 2007 and highest in 2013). In 2016, daily and weekly users comprised 37% of cannabis users and consumed 98% of the total amount of cannabis.

DISCUSSION

We used four large nationally representative surveys of substance use in Australia to estimate the proportion of total cannabis consumed by daily cannabis users. Based on four nationally representative surveys, we consistently estimated that daily users accounted for 81–85% of the total cannabis consumed. Our estimates are very similar to estimates reported for cannabis users in the United States by Burns *et al*[8].

There are several limitations in the present study. The NDSHS surveys may under-report total cannabis consumption because their response rates were just under 50% and the data are self-reported cannabis use. Daily cannabis users may also be under-represented in household surveys, as is known to occur with heavy drinkers[9], e.g. because they do not have a fixed abode or they live in transient accommodation or institutional

Table 2 Total cannabis consumption and proportion of cannabis use by strata.

2016	<i>Estimated consumption (joints)^a</i>	<i>95% credible interval</i>		<i>% of total annual consumption</i>	<i>95% credible intervals</i>	
Daily	377 577 000	324 031 000	429 899 000	84.49%	82.02%	86.57%
Weekly	59 611 000	52 806 000	66 258 000	13.39%	11.43%	15.61%
About once a month	6 019 000	5 136 000	6 884 000	1.35%	1.11%	1.62%
Every few months	2 576 000	2 260 000	2 895 000	0.58%	0.49%	0.69%
Once or twice a year	1 044 000	957 000	1 133 000	0.23%	0.20%	0.27%
Total	446 828 000					
2013	<i>Estimated consumption (joints)</i>	<i>95% Credible interval</i>		<i>% of total annual consumption</i>	<i>95% credible intervals</i>	
Daily	266 416 000	229 959 000	303 086 000	81.64%	78.84%	84.08%
Weekly	51 559 000	45 469 000	57 451 000	15.86%	13.59%	18.40%
About once a month	5 508 000	4 680 000	6 327 000	1.69%	1.40%	2.03%
Every few months	1 835 000	1 612 000	2 060 000	0.56%	0.48%	0.66%
Once or twice a year	792 000	727 000	857 000	0.24%	0.21%	0.28%
Total	326 111 000					
2010	<i>Estimated consumption (joints)</i>	<i>95% Credible interval</i>		<i>% of total annual consumption</i>	<i>95% credible intervals</i>	
Daily	336 053 000	2 911 978 000	381 264 000	84.80%	82.65%	86.73%
Weekly	51 952 000	46 823 000	57 184 000	13.16%	11.40%	15.09%
About once a month	5 460 000	4 680 000	6 207 000	1.38%	1.15%	1.64%
Every few months	1 862 000	1 655 000	2 073 000	0.47%	0.40%	0.55%
Once or twice a year	758 000	695 000	821 000	0.19%	0.17%	0.22%
Total	396 085 000					
2007	<i>Estimated consumption (joints)</i>	<i>95% Credible interval</i>		<i>% of total annual consumption</i>	<i>95% credible intervals</i>	
Daily	295 556 000	254 423 000	336 721 000	85.67%	83.39%	87.70%
Weekly	41 824 000	36 585 000	47 018 000	12.17%	10.29%	14.22%
About once a month	4 899 000	4 088 000	5 698 000	1.43%	1.15%	1.74%
Every few months	1 833 000	1 581 000	2 085 000	0.53%	0.44%	0.64%
Once or twice a year	6 701 000	606 000	733 000	0.20%	0.17%	0.23%
Total	344 783 000					

^aAll estimates were rounded to the nearest 1000.

settings. Survey participants may also underestimate their consumption. Both frequency and quantity were not precisely measured for the purpose of this study. We have estimated total consumption based on joints, as detailed consumption data on the type of cannabis used was not available. Potency data [as measured by delta-9-tetrahydrocannabinol (THC) content] were also not available. It is possible that daily users may consume cannabis that is more potent. For these reasons, our estimates may provide a lower bound on the proportion of

population cannabis consumption accounted for by daily users. Lastly, this study was not pre-registered on any publicly available platform, and the results should be considered exploratory.

Our findings show that the population distribution of the cannabis consumption is much like that of alcohol, in that daily users accounted for the majority of total consumption. This suggests that jurisdictions that have legalized cannabis should discourage heavy cannabis use by imposing taxes on cannabis products (in proportion to

their potency), strengthening social norms that discourage heavy consumption, restricting marketing practices that target heavy users and screening and intervening with the heaviest cannabis users who are seen in primary care medical settings[1].

CONCLUSION

In Australia between 2007 and 2016, we estimated that 81–85% of all cannabis was consumed by 16% of cannabis users who used daily. Weekly users and daily users together accounted for an estimated 98% of all cannabis consumed in Australia.

Declaration of interests

None.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 Number of bongos and joints consumed in a day by type of cannabis users.

Appendix 2 Technical details about simulating number of days of cannabis use.