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Research paper

Integrating environmental and self-report data to refine cannabis prevalence estimates in a major urban area of Switzerland

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ABSTRACT

Background: Cannabis consumption is a topical subject because of discussions about reviewing current regulations. In this context, having a more comprehensive approach to assess and monitor prevalence and consumption is highly relevant. The objective of this work was to refine current estimates about prevalence of cannabis use by combining self-report data and results derived from wastewater analysis.
Methods: Self-report data was retrieved from surveys conducted in Switzerland and Europe. Wastewater samples were collected at the wastewater treatment plant of Lausanne, western Switzerland, over a 15 months period. The occurrence of 11-nor-9-carboxy-delta-9-tetrahydrocannabinol (THC-COOH), a specific metabolite of delta-9-tetrahydrocannabinol (THC), was monitored. Bayesian hierarchical models were used to estimate consumption, prevalence and number of cannabis users in the investigated area.
Results: According to survey data, 12-months prevalence in western Switzerland was estimated to 6.2% of the population aged 15 or older, with an estimated daily cannabis consumption of 8.1 g day^{-1}·1000 inhab^{-1} (at 11.2% purity). The integrative model comprising self-report and wastewater data substantially reduced the uncertainty in the estimates and suggested a last-year prevalence of 9.4%, with a daily cannabis consumption of 14.0 g day^{-1}·1000 inhab^{-1}.
Conclusion: Although in the same order of magnitude, consumption and prevalence estimates obtained with the integrative model were 78% and 52% higher compared to self-report figures, respectively. Interestingly, these figures are similar to discrepancies observed when comparing self-reported alcohol consumption and sales or tax data. The suggested integrative model allowed to account for known sources of uncertainty and provided refined estimates of cannabis prevalence in a major urban area of Switzerland.

Introduction

In recent years, there has been a rapid increase in the number of studies focusing on monitoring illicit drug use through wastewater analysis (also referred to as wastewater-based epidemiology (WBE)) at the regional (Meyer, Vollerthun, & Hasselbach, 2015), national (Been et al., 2016; Tscharke, Chen, Gerber, & White, 2015; Zuccato et al., 2016) and international level (Ort et al., 2014; Thomas et al., 2012). These studies have shown how WBE can be integrated with existing surveillance methods to improve our current understanding about illicit drug use, eventually promoting the improvement of existing and the development of new policies and prevention measures.

Due to its widespread use and high prevalence rates (European Monitoring Centre for Drugs & Drug Addiction, 2015a), cannabis has been among the target substances since the first applications of the approach (Castiglioni et al., 2006). Better understanding the extent of its use is important for policy makers seeking to hamper the health and social impacts of cannabis consumption and trade. This is particularly important with regards to discussions about legalising its use and regulating the markets (Caulkins & Kilmer, 2013; European Monitoring Centre for Drugs & Drug Addiction, 2015b), which are also highly topical in Switzerland (Federal Council, 2013; National Drug Policy Coordination, 2015; Zobel & Marthaler, 2014). However, current methods used to estimate prevalence and consumption of cannabis, in particular general

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population surveys relying on self-reported use, suffer from potential (under or over) reporting biases, but also from under-coverage of marginalised drug users which are hard to reach (European Monitoring Centre for Drugs & Drug Addiction, 2009).

Wastewater based epidemiology could thus provide complementary information about the extent of cannabis use. In this context, most attention has been given to 11-nor-9-carboxy-delta-9-tetrahydrocannabinol (THC-COOH), one of the metabolites of the major active compound found in cannabis, i.e. delta-9-tetrahydrocannabinol (THC). The analysis of THC-COOH and back-estimation of THC consumption, referred to as "back-calculations", are challenging (Ort et al., 2014). Although THC-COOH has been shown to be stable in sewer conditions over longer periods of time, potential losses during sample preparation steps have been highlighted (Heuett, Ramirez, Fernandez, & Gardinali, 2015; Mccall et al., 2016; Senta, Krizman, Ahel, & Terzic, 2014). These can however be partly accounted for using stable isotope-labelled internal standards. Consumption estimates derived from wastewater analysis, were initially computed using only data relative to urinary excretion of THC-COOH (Postigo, de Alda, & Barceló, 2011; Zuccato, Chiabrando, Castiglioni, Bagnati, & Fanelli, 2008), however faecal excretion is known to be the major route by which THC and its metabolites are eliminated from the body (Huestis, 2007; Wall & Perez-Reyes, 1981; Wall, Sadler, Brine, Taylor, & Perez-Reyes, 1983). Considering that at pH values commonly measured in wastewater (i.e., 7.5) THC-COOH is expected to be ionized, and thus almost completely dissolved (Khan & Nicell, 2012), using only excretion rates relative to urine will overestimate consumption. The relatively low proportion of THC-COOH found to be adsorbed onto suspended solids (Heuett et al., 2015; Senta, Krizman, Ahel, & Terzic, 2013) further supports that what is excreted via faces will be dissolved in wastewater. Unfortunately, data about faecal excretion of THC-COOH is limited and obtaining precise estimates about cannabis use based only on WBE remains challenging. Thus, it is mandatory to include other, complementary, sources of information to corroborate the obtained estimates.

In regards of these observations, the objective of the present work consisted in monitoring the occurrence of THC-COOH in wastewater and combining the collected data to results from epidemiological surveys. For this, i) wastewater samples were collected over a period of 15 months at the inlet of the wastewater treatment plant (WWTP) of a city in western Switzerland. ii) The occurrence of THC-COOH was monitored and, through a Bayesian hierarchical model, used to estimate the amounts of cannabis used. iii) An additional model was developed to estimate consumption and prevalence based on survey data. iv) Finally, the two models were combined to obtain a refined estimate of both consumption and prevalence.

Material and methods

Wastewater sampling and instrumental analysis

Wastewater samples were collected at the inlet of the wastewater treatment plant (WWTP) of the city of Lausanne, in western Switzerland. The WWTP serves the city itself and 15 additional municipalities in its surroundings, for a total population of approximately 223,900 inhabitants (census based). Samples were collected at the influent of the WWTP using an autosampler (6712FR ISCO refrigerated (4 °C) autosampler, Teledyne ISCO, Lincoln, NE), from Tuesday to Wednesday and from Saturday to Sunday (12 PM to 12 PM) every second and forth week of the month, over a 15 months period (between October 2013 and December 2014). Hourly samples were collected time-proportionally (at 5 min frequency) and then manually mixed in a flow-proportional manner to obtain 24 h composite samples. Details about the procedure used to process the samples are reported elsewhere (Been et al., 2014). After processing and extraction, samples were analysed on a UHPLC system (1290 Infinity, Agilent, Santa Clara, CA, USA) coupled to a triple quadrupole mass spectrometer (5500 QTrap, ABSciex, Ontario, Canada) to determine THC-COOH concentrations. The analytical method was fully validated and additional details about its performance are reported in the Supporting Information.

Modelling and data analysis

To estimate prevalence of cannabis consumption in the investigated population, a Bayesian hierarchical model was implemented. Furthermore, Markov Chain Monte Carlo (MCMC) simulations were used to estimate model parameters (Gelman et al., 2013; Hamra, MacLehose, & Richardson, 2013). The model used in this context is presented in Fig. 1 in the form of a directed acyclic graph (DAG). The latter illustrates the causal relationship

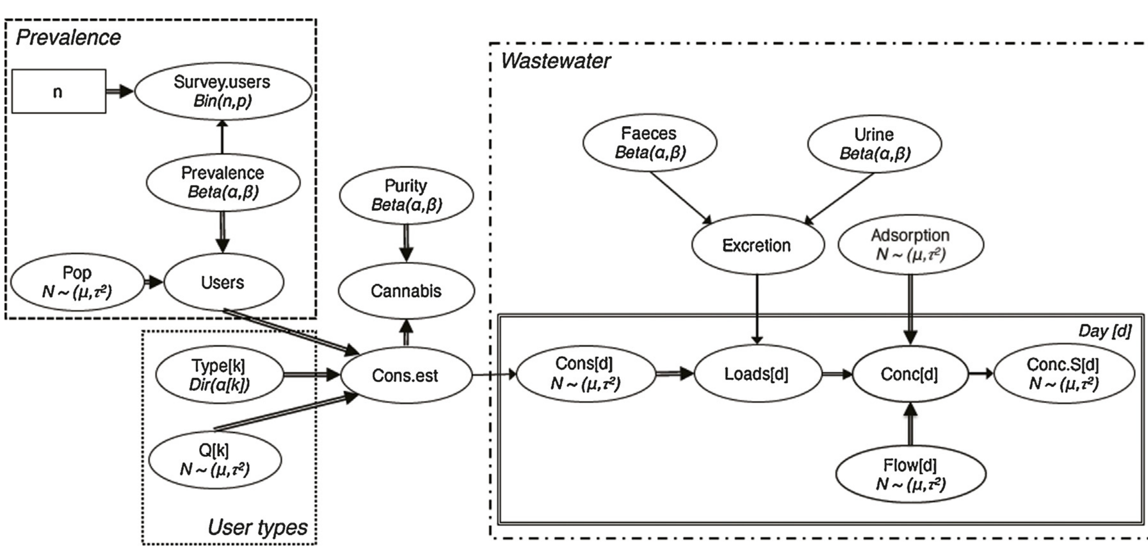

Fig. 1. Directed acyclic graph illustrating the hierarchical model used to estimate prevalence of cannabis consumption in the investigated area. Nodes represent stochastic variables (round) and constants (squares). Arrows represent stochastic (single) and logical (double) relationships. *Prevalence*: refers to the modelling of prevalence of cannabis consumption in the investigated area; *User types*: refers to the modelling of user types and their daily consumption; *Wastewater*: refers to modelling of excretion, occurrence in wastewater and analysis of THC-COOH and was adapted from previous work by Jones et al. (2014). See Table 1 for details about each node.