

# Cannabis Surveillance With Twitter Data: Emerging Topics and Social Bots

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**Objectives.** To use publicly accessible data from people who post to Twitter to rapidly capture and describe the public's recent experiences with cannabis.

**Methods.** We obtained Twitter posts containing cannabis-related terms from May 1, 2018, to December 31, 2018. We used methods to distinguish between posts from social bots and nonbots. We used text classifiers to identify topics in posts (n = 60 861).

**Results.** Prevalent topics of posts included using cannabis with mentions of cannabis initiation, processed cannabis products, and health and medical with posts suggesting that cannabis could help with cancer, sleep, pain, anxiety, depression, trauma, and posttraumatic stress disorder. Polysubstance use was a common topic with mentions of cocaine, heroin, ecstasy, LSD, meth, mushrooms, and Xanax along with cannabis. Social bots regularly made health claims about cannabis.

**Conclusions.** Findings suggest that processed cannabis products, unsubstantiated health claims about cannabis products, and the co-use of cannabis with legal and illicit substances warrant considerations by public health researchers in the future. (*Am J Public Health*. Published online ahead of print December 19, 2019: e1–e6. doi:10.2105/AJPH.2019.305461)

The legalization of cannabis through state-level medical cannabis and adult (21 years and older) recreational use laws has lowered prices and increased the availability of cannabis products in the United States.<sup>1</sup> Currently, a total of 33 states and the District of Columbia have legalized medical cannabis, and 11 states and the District of Columbia have legalized cannabis for adult recreational use.<sup>2</sup> The 2018 National Survey on Drug Use and Health found that past-month cannabis use was highest among adults aged 18 to 25 years (22.1%), compared with adolescents aged 12 to 17 years (6.7%) and adults aged 26 years and older (8.6%).<sup>3</sup> Acute health outcomes associated with cannabis use include impaired short-term memory, impaired attention, impaired coordination, and sleep problems,<sup>3</sup> and repeated cannabis use is associated with potential for cannabis dependence, increased risk of other drug and alcohol use disorders, and increased risk of schizophrenia among individuals with genetic vulnerability.<sup>3</sup> There is also substantial evidence of a link between cannabis use and increased risk of motor vehicle crashes.<sup>4</sup>

Around 1 in 10 cannabis users will become dependent; however, for individuals who begin using cannabis as adolescents, 1 in 6 will become dependent.<sup>4</sup> Several longitudinal studies have suggested that heavy cannabis use during adolescence may lead to lower cognitive functioning and IQ during adulthood.<sup>5,6</sup>

Publicly accessible data from people who post to social media platforms, such as Twitter, can be used to rapidly capture and describe the context of cannabis use.<sup>7,8</sup> Twitter is used by 22% of US adults (24% of men, 21% of women, 21% of Whites, 24% of African Americans, and 25% of Hispanics) with 42% of users on the platform daily.<sup>9</sup> Twitter is also used by 32% of adolescents (aged 13–17 years) in the United

States.<sup>10</sup> Previous analyses of cannabis-related posts to Twitter, drawn from brief time periods and relatively small amounts of data, have provided the initial information on what the public organically discusses, including the desire to use cannabis, mentions of perceived health benefits, legalization efforts, and frequency of use.<sup>11</sup> Krauss et al. analyzed a sample of posts to Twitter from 1 month in 2014 and found that tweets commonly mentioned cannabis and alcohol co-use.<sup>12</sup> However, cultural trends in the United States, the cannabis consumer marketplace, and state cannabis policies are rapidly changing. The context and experiences associated with cannabis use rapidly change as well, making it important to provide recent information on cannabis. The goal of this study was to identify and describe cannabis-related topics of conversation on Twitter to inform the public health community.

## METHODS

We obtained Twitter (<https://twitter.com>) posts containing the following cannabis-related terms: “blunt,” “bong,” “budder,” “cannabis,” “cbd,” “ganja,” “hash,” “hemp,” “indica,” “kush,” “marihuana,” “marijuana,” “reefer,” “sativa,” “thc,” and “weed,” from May 1, 2018, to December 31, 2018. These terms were informed by previous research and topic matter experts.<sup>11–14</sup> There was a total of n = 53 177 048 posts containing these terms

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during this time. Similar to previous research,<sup>15,16</sup> we removed all retweets ( $n = 34\,095\,967$ ) and sampled out a subset of the remaining tweets ( $n = 19\,081\,081$ ) to conduct analyses. We accomplished this by grouping tweets by the week in which they were posted (this allowed us to maintain temporal characteristics of the tweets when sampling). We then sampled proportionally from each cannabis-related term by week.<sup>17</sup> From this, we sampled out 102 701 tweets from 75 751 unique accounts.

Next, we filtered out non-English tweets and tweets that contained key terms but did not refer to cannabis—as in the case of Emily Blunt (actress), James Blunt (singer), and hash browns (food), among others. Then, we filtered out social bots, or automated Twitter accounts designed to produce content and engage with legitimate human accounts on Twitter.<sup>18</sup> Social bots may bias the data limiting our ability to reliably describe the public's recent experience with cannabis.<sup>19</sup> To distinguish between nonbots and social bots, we used Botometer.<sup>20</sup> This program analyzes the characteristics of a Twitter account and gives it a score based on how likely the account is to be a social bot. This method of social bot detection is considered state of the art and has been employed in previous studies focused on social bots and public health.<sup>21–23</sup> Through these procedures, we arrived at  $n = 60\,861$  tweets from 47 760 nonbots and  $n = 8874$  tweets from 2871 social bots. To protect privacy, no tweets were reported verbatim in this report.

To prepare tweets for data analysis we performed a number of transformations, including the following:

1. Basic normalization. This encompasses lowercasing all tweets and removing extra spaces, punctuation, and special characters such as brackets.
2. Stop word removal. Words such as “a” and “the” are heavily represented in the English language, adding to the syntax but rarely adding to the meaning of a sentence. As such, we removed these words.
3. Normalizing Twitter account mentions. On Twitter, @account\_name is used to tag accounts and pages in a post. The name of each account tagged has little importance to our study, but we wanted to maintain information on the number of accounts tagged. Therefore, all @account\_name occurrences in the tweets were replaced by @person—a common token for all accounts.
4. Lemmatization. Words such as “walked” and “walk” can be conflated in our analysis, so we broke down words into their basic form by removing inflections and variants.
5. Nonprintable character removal. Unicode characters in tweets are often used for emoticons or as symbols from other languages. Because we are interested in tweets in English, we can remove these symbols without much loss in the meaning of the sentence.
6. Removal of hashtags and URLs. Hashtags are useful for filtering out tweets that relate to a group (e.g., #weed) but are not necessary to analyze when dividing a group into further topics. As such, we discarded hashtags. URLs embedded in the tweet were usually links to images (which on Twitter are shown as embedded images) and external links to other Web sites. Because we cannot obtain much information about a Web site from its URL, we discarded it.
7. CBD and hemp use (mentions of using CBD oil, hemp oil, CBD-infused products),
8. Appeal or abuse liability (mentions of needing, wanting, or craving cannabis),
9. Polysubstance use (mentions of other substances including alcohol, painkillers, and psychedelics), and
10. Cannabis industry (mentions of cannabis-related stocks, markets, and peripheral industries).

Although not prominent topics, but consistent with our previous research,<sup>15</sup> we looked for words and phrases that suggested underage use (mentions of cannabis use at school) and impairment (mentions of cannabis use at the workplace or driving under the influence).

We classified each tweet to 1 or more topics based on the presence of at least 1 topic-related pattern. A pattern could be a one-gram, a bigram, or any group of words that must occur in the normalized tweets in a given order. We accomplished this by using a rule-based classification script written in Python with which we examined each tweet for the presence of a specified set of patterns representing a topic. Because there was topic overlap, we report the percentage of overlap between each topic by utilizing a confusion matrix as a visualization tool. Each cell in the matrix represents the intersection of 2 topics. The value of the cell represents the percentage of the total corpus that belongs to both topics. For example, a hypothetical post such as “Hey @person share your edibles” would be classified under “person tagging” and “processed product usage.” The number of posts containing both would be found at the intersection of the matrix for these 2 topics.

## RESULTS

The total coverage of the 12 topics constituted 58.14% of all tweets in the corpus from nonbots (Table 1). The remaining 41.86% of tweets were too varied to be classified into a single topic with meaningful coverage (i.e., coverage of each subsequent topic would be less than 1% of total tweets). The most prevalent topic in this corpus was person tagging at 33.60% followed by using cannabis at 11.89%. Among using cannabis,

TABLE 1—Prevalence of Topics From Nonbot Corpus of Tweets: May 1, 2018, to December 31, 2018

	Person Tagging, No. (%)	Using Cannabis, No. (%)	Health and Medical, No. (%)	Legality, No. (%)	Buy/Sell, No. (%)	Processed Product Usage, No. (%)	CBD and Hemp Use, No. (%)	Appeal or Abuse Liability, No. (%)	Polysubstance Use, No. (%)	Cannabis Industry, No. (%)	Impairment, No. (%)	Underage Use, No. (%)
Underage use	87 (0.14)	68 (0.11)	2 (0.00)	6 (0.01)	17 (0.03)	7 (0.01)	0 (0.00)	3 (0.00)	25 (0.04)	0 (0.00)	2 (0.00)	215 (0.35)
Impairment	107 (0.18)	77 (0.13)	12 (0.02)	32 (0.05)	13 (0.02)	6 (0.01)	0 (0.00)	5 (0.01)	4 (0.01)	0 (0.00)	288 (0.47)	
Cannabis industry	217 (0.36)	22 (0.04)	34 (0.06)	75 (0.12)	47 (0.08)	1 (0.00)	7 (0.01)	2 (0.00)	11 (0.02)	808 (1.33)		
Polysubstance use	618 (1.02)	241 (0.40)	42 (0.07)	79 (0.13)	60 (0.10)	43 (0.07)	18 (0.03)	20 (0.03)	1 504 (2.47)			
Appeal or abuse liability	267 (0.44)	160 (0.26)	29 (0.05)	15 (0.02)	51 (0.08)	17 (0.03)	10 (0.02)	1 614 (2.65)				
CBD and hemp use	503 (0.83)	11 (0.02)	345 (0.57)	53 (0.09)	177 (0.29)	165 (0.27)	1 661 (2.73)					
Processed product usage	948 (1.56)	62 (0.10)	127 (0.21)	71 (0.12)	183 (0.30)	2 260 (3.71)						
Buy/sell	939 (1.54)	136 (0.22)	193 (0.32)	201 (0.33)	3 051 (5.01)							
Legality	1 434 (2.36)	274 (0.45)	279 (0.46)	3 345 (5.50)								
Health and medical	1 231 (2.02)	218 (0.36)	3 416 (5.61)									
Using cannabis	1 965 (3.23)	7 235 (11.89)										
Person tagging	20 450 (33.60)											

Note. CBD = cannabidiol.

2.61% of posts were indicative of cannabis initiation including phrases such as “first time.” Health and medical was the next most prevalent topic at 5.61%. Among health and medical, cannabis was suggested to help with cancer, plantar fasciitis, Crohn’s disease, sleep, pain, anxiety, depression, trauma, and post-traumatic stress disorder, among others. Legality was the next most prevalent topic at 5.50%, followed by buy/sell at 5.01%, processed product usage at 3.71%, CBD and hemp use at 2.73%, and appeal or abuse liability at 2.65%. Polysubstance use was a common topic at 2.47%. Among polysubstance use, beer, wine, vodka, tequila, cocaine, heroin, ecstasy, LSD, meth, mushrooms, and Xanax were mentioned along with cannabis. Cannabis industry comprised 1.33% of posts. Impairment and underage use were uncommon topics at 0.47% and 0.35%, respectively.

The total coverage of the same 12 topics constituted 55.60% of all tweets in the corpus from social bots. Comparing the 2 corpuses,

some topics have similar prevalence while other topics stand out with differences. For example, the largest difference in prevalence in topics between corpuses was found in person tagging (nonbots at 33.60% vs social bots at 11.09%), followed by using cannabis (nonbots at 11.89% vs social bots 3.88%) and health and medical (nonbots at 5.61% vs social bots at 10.13% Table 2).

## DISCUSSION

This study is one of the largest Twitter studies to date focused on cannabis-related conversations, describing more than 60 000 unique posts from more than 40 000 unique accounts. We identified a number of important, novel topics of conversation ranging from cannabis initiation to health claims about cannabis’ ability to relieve an array of ailments, including cancer, depression, and trauma. Posts discussed edibles, hemp, legalization, buying products, and cannabis’ appeal or

abuse liability, among other topics. We found that Twitter users often discussed polysubstance use, with beer, wine, vodka, tequila, cocaine, heroin, ecstasy, LSD, meth, mushrooms, and Xanax mentioned along with cannabis. This is also the first study to date, to our knowledge, to distinguish cannabis-related topics of conversations by social bots and nonbots on Twitter. When we compared posts from nonbots with posts from social bots, we found that some topics comprised similar proportions while other topics stood out with differences. For example, posts indicating that cannabis could allay health concerns represented a larger proportion of posts by social bots compared with nonbots. Unsubstantiated health claims perpetuated by social bots may have offline consequences, such as leaving Twitter users with the impression that cannabis use can allay health problems such as cancer.

In line with previous research,<sup>15,16</sup> person tagging was a predominant theme in the current study of cannabis-related posts to

**TABLE 2—Comparison of Prevalence of Topics Between Social Bots and Nonbots: May 1, 2018, to December 31, 2018**

Topic	Nonbots, %	Bots, %	Delta, <sup>a</sup> %
Appeal or abuse liability	2.65	0.59	2.07
Buy/sell	5.01	4.73	0.28
CBD and hemp use	2.73	6.41	-3.68
Cannabis industry	1.33	3.13	-1.81
Health and medical	5.61	10.13	-4.52
Impairment	0.47	0.20	0.27
Legality	5.50	4.88	0.62
Person tagging	33.60	11.09	22.51
Polysubstance use	2.47	1.15	1.32
Processed product usage	3.71	4.02	-0.31
Underage use	0.35	0.10	0.25
Using cannabis	11.89	3.88	8.01

Note. CBD = cannabidiol.

<sup>a</sup>The difference in percentage.

Twitter. The act of person tagging is indicative of a distinct communicative practice in which Twitter users communicate their attitudes and experiences with cannabis. Posts classified under person tagging consistently used @Person to involve others in conversations about cannabis. These online messages may have an impact on cannabis use. For example, Cabrera-Nguyen et al. found that current cannabis use was significantly associated with higher levels of exposure to procannabis content on Twitter among young adults.<sup>24</sup> Reditis et al. demonstrated that adolescents who reported seeing messages about the benefits of cannabis use on social media were more likely to report cannabis use than adolescents reporting not seeing such messages.<sup>25</sup> In the context of this previous research, the current study's findings should be important to the public health community, as repeated exposure to procannabis messaging and cannabis use by others can influence the social norms of those exposed to the content and lead to imitation of the behaviors.<sup>26</sup>

Using cannabis, including initiation of use, was a prevalent topic in the current study. Cannabis-related posts to Twitter can also be leveraged for intervention efforts to curb

initiation.<sup>27</sup> Interventions could be designed to engage with Twitter users posting about their first-time experience with cannabis. Such interventions could inform participants experimenting with cannabis about the health consequences of use in hopes to prevent dependence.

Processed product usage and CBD and hemp use were also common topics in the current study, and similar to previous research. For example, analysis of edible-related posts to Twitter demonstrated that cannabis edibles were generally positively perceived among Twitter users despite some posts suggesting that edibles were unreliable (e.g., variability in effect intensity and duration).<sup>7</sup> Cavazos-Rehg et al. analyzed a sample of edible-related posts to Twitter from 1 month in 2015 and found that most posts normalized or encouraged edibles use and described the intense or long-lasting effects following use.<sup>8</sup>

A content analysis of tweets about high-potency cannabis demonstrated that posts often mentioned the physiological and psychological effects from use, and that the most common physiological effects were passing out and respiratory effects, such as coughing.<sup>28</sup> Despite positive perceptions of cannabis concentrates, the amount of tetrahydrocannabinol (THC), the cannabinoid responsible for intoxication found in some cannabis concentrates and extracts, can range from 50% to more than 80%,<sup>29</sup> while high-potency cannabis plants have THC levels around 20% to 25%.<sup>4,30</sup> While not lethal, overdoses are common when one is using cannabis concentrates and extracts,<sup>31</sup> and high amounts of THC may produce acute psychotic symptoms (e.g., hallucinations, delusions, and anxiety) in some users.<sup>32</sup> Interventions could be designed to monitor Twitter in hopes of identifying high-risk cannabis users. Messages could be designed to inform Twitter users about the risks of high-potency cannabis products in hopes of reducing overdoses and dependence.

Analyses of cannabis-related posts to Twitter from 1 month in 2014 identified a number of themes including a desire to use cannabis, mentions of health benefits, legalization efforts, and frequency of use.<sup>11</sup> Appeal or abuse liability, health and medical, and legality were common topics in the current study suggesting continuity of cannabis-related discussions on Twitter over the past

few years. Since 2014, several additional states have voted to legalize medical cannabis<sup>2</sup> and have also voted to legalize recreational adult use of cannabis.<sup>2</sup> Among adults living in a state with legalized recreational cannabis, more than half (54.8%) reported seeing cannabis advertising during the past month, regardless of individual cannabis use.<sup>33</sup> As states continue to legalize access to cannabis products, cannabis-related discussions about product appeal, health claims, and legalization may continue to be popular topics on Twitter. Local and state public health agencies can use Twitter to disseminate evidence-based information about cannabis use.

Krauss et al. analyzed a sample of posts to Twitter from 1 month in 2014 and found that tweets commonly mentioned polysubstance use (i.e., cannabis and alcohol).<sup>12</sup> Our study corroborates the findings from this initial study, and extends them by demonstrating that Twitter users reported cannabis use along with other substances, including heroin, ecstasy, LSD, cocaine, and prescription drugs. There is moderate evidence that cannabis use is likely to increase the risk of developing a substance abuse disorder for other substances, including alcohol, tobacco, and other illicit drugs, with some studies indicating that the risk of developing substance use disorders is higher among younger cannabis users.<sup>4</sup>

In contrast to previous Twitter studies focused on substance (i.e., nicotine) use,<sup>15</sup> the current study found few posts indicative of underage use of cannabis. Thompson et al. assessed cannabis-related content posted to Twitter by adolescents, finding that a majority of the tweets reflected a positive attitude toward cannabis, and 42.9% indicated personal use.<sup>34</sup> Adolescents' posts also suggested that their parents were supportive of their cannabis use.<sup>34</sup>

In this study, we found that posts from social bots comprised smaller proportions of person tagging, but almost double the proportion of posts pertaining to health and medical compared with nonbots. Social bots have previously been found to spread unsubstantiated health claims on Twitter. For example, in 2017, Allem et al. found that social bots were more than 2 times as likely to make claims about the effectiveness of electronic cigarettes in smoking cessation compared with nonbots.<sup>23</sup> In 2018, Martinez et al. found similar results, suggesting that the



majority of the Twitter data they collected pertaining to electronic cigarettes originated from social bots and often touted the use of electronic cigarettes in cessation.<sup>22</sup> Most recently, Broniatowski et al. reported that social bots were responsible for disseminating antivaccine messages in the United States.<sup>21</sup> Taken all together, social bots, with their ability to infiltrate online discussions and rapidly spread unsubstantiated health claims on Twitter, may pose a public health concern. Future research should determine if exposure to such claims is associated with offline attitudes and behaviors.

According to a recent review of medical use of cannabis published in the *Journal of American Medical Association*, only a few cannabinoids have high-quality evidence to support their use and are approved for medical use by the US Food and Drug Administration.<sup>35</sup> In brief, these include the use of cannabis to help with chemotherapy-induced nausea and vomiting, for appetite stimulation in conditions that cause weight loss (e.g., AIDS), and for the management of 2 forms of pediatric epilepsy.<sup>35</sup> Given the amount of health claims identified in the current study, these findings may serve as an early warning to those who run or own social media platforms. Tech companies, like Twitter, have shown concern over unsubstantiated health claims appearing on their platforms. Cannabis may be an emerging area for unsubstantiated health claims on Twitter, requiring the company to regulate content internally or face external regulations from state or federal agencies.

## Limitations

This study focused on posts to Twitter, and findings may not extend to other social media platforms. The posts in this study were collected from an 8-month period and may not extend to other time periods. Data collection relied on Twitter's Streaming Application Programming Interface, which prevented collection of posts from private accounts. Findings may not generalize to all Twitter users or to the US population. Not all tweets were covered by the established categories, and topics of conversation were not segmented by geographic location, preventing this study from determining the impact of different state cannabis policies on the public's experience with cannabis. In some instances,

one-grams and bigrams used to define topics may have multiple meanings that were ignored in the current study. For example, the phrase "first time" in cannabis-related posts may not always indicate initiation but rather may describe an established cannabis user in a novel situation or context. Similarly, it is unclear that the word "school" always identified underage use, as college students or other educational professionals may be adult cannabis users.

## Public Health Implications

Use of cannabis as well as initiation, health-related claims about cannabis products, and polysubstance use were common contexts associated with Twitter posts about cannabis. These results suggest that high-potency cannabis products, unsubstantiated health claims about cannabis products, and the co-use of cannabis with legal and illicit substances warrant considerations by public health researchers in the future. Twitter may be a platform to engage with those experimenting with cannabis as well as established cannabis users to inform them of the potential for cannabis dependence and additional health consequences of use. This study also highlights the ability of Twitter data to help researchers understand the public's recent experiences with cannabis. *AJPH*

## CONTRIBUTORS

J. Allem received funding for the study. All authors designed the concept of the study and analyzed the data. J. Allem and P. Escobedo drafted the first version of the article. L. Dharmapuri provided critical revisions of the article for important intellectual content. All authors approved the final version of the article.

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## CONFLICTS OF INTEREST

The authors report no conflicts of interest.

## HUMAN PARTICIPANT PROTECTION

All analyses relied on public, anonymized data; adhered to the terms and conditions, terms of use, and privacy policies of Twitter; and were performed under institutional review board approval from the University of Southern California.

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