



Short Report

Public interest in Δ^8 -Tetrahydrocannabinol (delta-8-THC) increased in US states that restricted Δ^9 -Tetrahydrocannabinol (delta-9-THC) useEric C. Leas^{a,*}, Alicia L. Nobles^b, Yuyan Shi^a, Erik Hendrickson^a^aHerbert Wertheim School of Public Health and Human Longevity Science, University of California San Diego, La Jolla, CA, USA^bDivision of Infectious Diseases and Global Public Health, Department of Medicine, University of California San Diego, La Jolla, CA, USA

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ABSTRACT

Background: There is an expanding unregulated market for a psychotropic compound called Δ^8 -Tetrahydrocannabinol (delta-8-THC) that is being derived from hemp, but there are no empirical estimates of public interest in this compound.

Methods: To measure public interest, we obtained yearly Google query fractions (QFs) that mentioned delta-8-THC (i.e., “delta 8,” “delta-8,” or “ Δ^8 ”) for the past decade (from January 2011 through August 2021) for every country and territory in the world and every state in the United States (US) from Google Trends. We also obtained the same trends for the last complete month of data for all US states (July 2021) to compare across cannabis use policies. We summarized QFs across years, countries, US states and cannabis policies in US states using linear regression, means and ratios. We estimated raw search counts for the US using comscore.com.

Results: The global rate of delta-8-THC searches was stable between 2011 and 2019 before increasing by 257.0% from 2019 to 2020 and 705.0% from 2020 to 2021. In 2021, the rate of delta-8-THC searches in the US was at least 10 times higher than the rates in other countries or territories. In absolute terms, there were 22.3 million delta-8-THC searches in the US in the first 8 months of 2021 alone. Increases in delta-8-THC searches from 2020 to 2021 occurred in all 50 US states and the District of Columbia (Mean 854.2%; range = 256.4% – 2831.2%) but continued to vary substantially between states in 2021. In July 2021, the legal status of delta-9-THC use across US states explained 49.0% of the variance in delta-8-THC QFs between US states ($R^2 = 0.490$; $p < 0.001$) and was inversely associated, where delta-8-THC QFs were higher in jurisdictions with stricter cannabis use policies.

Conclusion: Public interest in delta-8-THC increased rapidly in 2020 and 2021 and was particularly high in US states that restricted delta-9-THC use. Jurisdictions should clarify whether delta-8-THC can be sold as a hemp product.

Background

There is an expanding unregulated market for a psychotropic compound called Δ^8 -Tetrahydrocannabinol (delta-8-THC) that is being derived from hemp (Leas, 2021). Delta-8-THC has a nearly identical chemical structure with the primary psychotropic compound in cannabis Δ^9 -Tetrahydrocannabinol (delta-9-THC) and produces a similar “high” (National Center for Biotechnology Information, 2021). Most cannabis strains produce minimal amounts of delta-8-THC, but larger quantities can be synthesized by chemically converting delta-8-THC from cannabidiol (CBD). The primary method of converting CBD to delta-8-THC yields a solution that also contains delta-9-THC, and several other cannabis-specific compounds called “cannabinoids” (Webster, Sarna & Mechoulam, 2004). This solution can be processed to remove the delta-

9-THC and other cannabinoids and then added to products such as candies and vaping products. At present, there is little evidence about whether toxic or otherwise harmful substances are produced as byproducts of the methods of converting CBD to delta-8-THC and may remain in the solutions, which makes it unclear if they produce products suitable for human consumption. This has led some jurisdictions like Colorado, one state in the United States (US), to disallow these conversion methods even though they permit recreational use of delta-9-THC (Colorado Department of Public Health & Environment, 2021).

A critical policy question is whether delta-8-THC can be legally synthesized from a non-psychoactive cannabis strain called “hemp.” To allow for the industrial uses of hemp, such as making paper or rope (Cherney & Small, 2016), many countries and territories have begun adopting legal definitions of hemp that are distinct from other cannabis

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strains (World Law Group, 2020). For example, in 2018 the US Congress removed “hemp,” which it defined as cannabis and cannabis derivatives with $\leq 0.3\%$ delta-9-THC, from the definition of “marijuana” in the US Controlled Substances Act (The United States Senate Committee on Agriculture, Nutrition & Forestry, 2018). However, since hemp contains CBD, it can be used as a precursor for synthesizing delta-8-THC. The methods for converting CBD to THC are not discussed in most hemp laws throughout the world, so the legality of the conversion methods remain unclear in most jurisdictions. In August 2020, the US Drug Enforcement Agency (DEA) promulgated that the use of any processes that create delta-9-THC as a byproduct at any point, which is the case when converting CBD to delta-8-THC, are in violation of federal law (National Archives & Records Administration Office of the Federal Register, 2020). However, whether the DEA has or will act on this remains unclear.

In the absence of clear rulings on the legal status of delta-8-THC, many opportunistic manufacturers have developed marketing strategies that evade cannabis and hemp laws (Leas, 2021). For example, one of the largest delta-8-THC manufacturers is headquartered in the US state of Indiana, where cannabis remains prohibited both recreationally and medicinally (3Chi, 2021). While US states that permit recreational cannabis use require products to be sold by licensed dispensaries, many manufacturers sell bulk quantities of delta-8-THC and pre-mixed products that resemble cannabis products directly through their websites. Some delta-8-THC manufacturers also have programs to ship their products wholesale to retailers, such as gas stations, vape shops and convenience stores that resell products evading licensing program requirements. Additional cannabis policies that could be evaded include requirements for potency or contaminant testing, age restrictions, as well as requirements for packing, labeling, and marketing.

While the public health issues related to delta-8-THC have been discussed in some editorials (Johnson-Arbor & Smolinske, 2021; Leas, 2021), we are aware of no empirical estimates of public interest in delta-8-THC. In this manuscript, we report on public interest for delta-8-THC—as measured in Google searches. Google is used by consumers to access information and websites to purchase products and provides a data stream that is increasingly used by epidemiologists to understand trends in public interest in health-related topics, products, and behaviors (Eysenbach, 2011). Data on Google searches has been used to study public interest in novel psychoactive compounds—including cannabinoids (Leas et al., 2019), synthetic cannabinoids (Curtis et al., 2015) and devices used to ingest cannabinoids such as vapes (Leas et al., 2021)—finding elevated interest in these products prior to availability of confirmatory information such as sales records, surveys, and poison control center data. Herein, we report on trends in Google search for delta-8-THC across the US and worldwide. Additionally, because delta-8-THC products escape many cannabis control laws, we assessed whether interest in delta-8-THC was elevated in jurisdictions that had stricter policies on cannabis use.

Methods

Data and measures

We obtained yearly trends in Google queries that mentioned delta-8-THC (i.e., “delta 8,” “delta-8,” or “Δ8”) for the past decade (from January 2011 through August 2021) for every country and territory in the world and every US state (including the District of Columbia) as well as monthly estimates for all US states for the last month with complete data (July 2021) at the time of analysis. All queries were obtained from Google Trends using the Google API Client library in Python (Google API Client, 2021). We removed mentions of “COVID” and “variant,” as the COVID-19 delta variant began spreading during the study period. Google automatically keyword-stems search terms such that all phrase variations of a keyword are queried. For example, our use of the keyword “delta-8” would also include the queries “delta-8-THC,” “delta-

8 THC,” “delta-8 tetrahydrocannabinol,” etc. Trends in Google queries were measured as query fractions (QFs), which estimate the number of searches that mention delta-8-THC keywords originating in the time frame and geography divided by the total number searches in the same time frame and geography and expressed in per 10 million searches.

We categorized US states according to the legal status of delta-9-THC in 4 ways: 1) fully legal medicinal and recreational use (“fully legal”), 2) medicinally legal and no criminal possession law for non-medicinal use (“medicinally legal and decriminalized”), 3) medicinally legal but a criminal possession law for non-medicinal use (“medicinally legal and criminalized”), and 4) fully illegal for medicinal and recreational use (“fully illegal”). For these comparisons, we restricted our data to the last observed month with complete data (July 2021) to account for the implementation of state recreational use laws in 2021 (occurring in Connecticut, New Jersey, New Mexico, and New York). Three states had passed recreational use laws but systems allowing sales were not implemented at the time of analysis (August 2021), so the legal status of delta-9-THC as of July 2021 was assumed for these: Montana (medicinally legal and decriminalized), Virginia (medicinally legal and decriminalized), and South Dakota (fully illegal).

Statistical analyses

To quantify growth in interest for delta-8-THC from year-to-year, we calculated the annual percent increase in QFs $[(QF_t - QF_{t-1}) / QF_{t-1}]$; where QF is the query fraction, t is the year of interest and $t-1$ is the preceding year] for all geographies and summarized these using means and the ranges of values. We calculated QF ratios to compare the relative differences in QFs between geographies at a given time point $[QF_{t, g1} / QF_{t, g2}]$; where QF is the query fraction, t is the time assessed and $g1$ and $g2$ are the geographies being compared]. We used means to summarize the query fractions across the legal statuses of delta-9-THC and the ratio of mean QFs to describe the magnitude of the difference $[\frac{\sum QF_{ls1}}{N_{ls1}} / \frac{\sum QF_{ls2}}{N_{ls2}}]$; where QF is the query fraction, N is the number of states with the legal status of interest, $ls1$ and $ls2$ are the legal statuses of delta-9-THC being compared]. We describe the percent of the variance in QFs between US states that was explained by difference in the legal status using an R^2 statistic, assessed the overall significance with an F Statistic, and assessed pairwise significance using Bonferroni-adjusted Student's t tests.

Finally, because Google does not provide an estimate of the total number of searches, we calculated an approximation for the period of interest (January 2021 to July 2021) using the following process. First, we obtained the monthly search total originating from US desktop computers for the month of May 2021 (the most recent estimate available in August 2021) from comscore.com (Comscore, 2021). We assumed this monthly desktop search total was constant in our study. Second, we adjusted this number by the fraction of searches originating from desktop computers (35%) estimated by the SEO company SISTRIX using their proprietary database (SISTRIX, 2021). Finally, we calculated an estimate for the total number of searches during this period using the following equation: $QF_p \cdot CS_t \cdot N_p \cdot AF$; where QF_p is the query fraction (in this case expressed per 1 search) for the period of interest p , CS_t is the comscore estimate of total monthly desktop search total available at the time of analysis t , N_p is the number of months in the study period p , and AF is the adjustment factor for the estimated proportion of Google searches that originated from desktop computers.

All calculations were made using R Version 4.0.4 (R Core Team, Vienna, Austria). Because all data were de-identified and publicly available, the University of California, San Diego institutional review board exempted the analyses from review.

Results

The global trend in searches for delta-8-THC was stable from 2011 through 2019, but then the rate of searches increased by 257.0% from 2019 to 2020 and 705.0% from 2020 to January-August in 2021

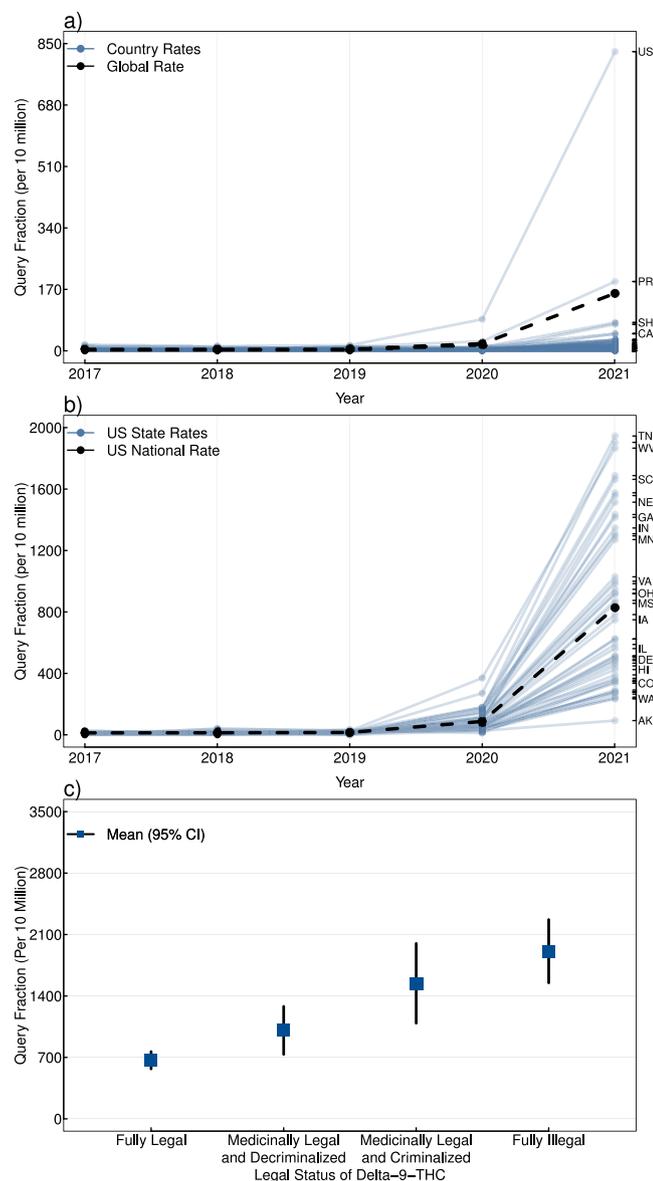


Fig. 1. Google Searches for Δ^8 -tetrahydrocannabinol (a) Highlights yearly Google searches from January 2017 to August 2021 worldwide (black line) and for every country in the world (blue lines); (b) highlights yearly Google searches from January 2017 to August 2021 for the entire United States (black line) and for every US state (blue lines); (c) highlights Google searches for July 2021 for all US states by the legal status, where blue squares and black lines indicate the mean and 95% CI for the states with each legal status of delta-9-THC in July 2021. Notes: Fully legal = fully legal medicinal and recreational use; Medicinally Legal and Decriminalized = medicinally legal and no criminal possession law for non-medicinal use; Medicinally Legal and Criminalized = medicinally legal but a criminal possession law for non-medicinal use; Fully Illegal = fully illegal for medicinal and recreational use; Country and US state codes are in the ISO 3166 alpha-2 format: <https://www.iso.org/iso3166-country-codes.html>.

(Fig. 1a). The growth in the global trend of delta-8-THC searches was driven predominantly by increases in the US, where the rate of delta-8-THC searches increased by 466.8% from 2019 to 2020 and by 850.2% from 2020 to January–August in 2021. By 2021 (January – August), the rate of searches for delta-8-THC in the US (QF = 828 per 10 million) was at least 10 times higher than rate of delta-8-THC searches in any other country or territory, with the next closest comparisons to a non-US territory being Saint Helena, Ascension, & Tristan da Cunha (QF = 78

per 10 million). In absolute terms, there were 22.3 million delta-8-THC searches in the US in the first eight months of 2021 alone. Increases in the rate of delta-8-THC searches from 2019 to 2020 occurred in 49 US states and the District of Columbia (Mean 608.6%; range = -56.7% – 2734.3%; with Alaska, Arkansas, and North Dakota undefined as they had QFs = 0 in 2019) (Fig. 1b). Increases in the rate of delta-8-THC searches from 2020 to 2021 occurred in all 50 US states and the District of Columbia (Mean 854.2%; range = 256.4% – 2831.2%). However, in the first eight months of 2021 the rate of searches varied substantially between US states, ranging from a high of 1945 per 10 million in Tennessee to a low of 93 per 10 million in Alaska.

The legal status of delta-9-THC use across US states explained 49.0% of the variance in delta-8-THC QFs between US states in July 2021 ($R^2 = 0.490$; $p < 0.001$) and had an inverse association such that interest in delta-8-THC increased with increasingly stricter cannabis policy (Fig. 1c). On average, delta-8-THC QFs in states prohibiting delta-9-THC use were 1.2 times higher than delta-8-THC QFs in states permitting medicinal use but criminalized non-medicinal possession ($p = 0.76$), 1.9 times higher than delta-8-THC QFs in states permitting medicinal delta-9-THC use and decriminalized non-medicinal possession ($p < 0.001$), and 2.8 times higher than delta-8-THC QFs in states permitting for both recreational and medicinal delta-9-THC use ($p < 0.001$). Additionally, delta-8-THC QFs in states permitting medicinal delta-9-THC use but criminalized non-medicinal possession were 1.5 times higher than in states permitting medicinal use and decriminalized non-medicinal possession ($p < 0.16$) and were 2.3 times higher than delta-8-THC QFs in states where delta-9-THC was permitted for both recreational and medicinal use ($p = 0.003$). Finally, delta-8-THC QFs in states permitting medicinal use and decriminalized non-medicinal possession were 1.5 times higher than delta-8-THC QFs in states where delta-9-THC was permitted for both recreational and medicinal use ($p = 0.54$).

Discussion

Public interest in delta-8-THC increased rapidly in 2020 and 2021 and nearly exclusively occurred in the US. Interest in delta-8-THC first began increasing the year after the US Congress removed hemp from the definition of marijuana in the US Controlled Substances Act (The United States Senate Committee on Agriculture, Nutrition & Forestry, 2018) and increased in every US state from 2020 to 2021. Yet, by 2021 public interest in delta-8-THC varied considerably across US states. About half of the variation in interest between US states was explained by differences in the legal status of delta-9-THC across states and was inversely associated with progressively stricter policies governing delta-9-THC.

The growth in searches following legalization of hemp in the US as well as the greater interest in US States with more restrictive delta-9-THC policies suggests that delta-8-THC may be meeting a demand for legal use of THC in markets that do not permit use of delta-9-THC. The one-year lag following the legalization of hemp could potentially be explained by a need for developing an infrastructure to produce and ship delta-8-THC products. For example, one manufacturer claims to have created “USA’s first federally legal THC-dominant product since cannabis prohibition started,” after it developed a method of synthesizing delta-8-THC in September of 2019 (3Chi, 2021). By 2021, hundreds of Delta-8-THC manufacturers existed throughout the US, and many offered to ship products to consumers and wholesale to retailers in states that did not permit use of delta-9-THC (Leas, 2021).

These findings should be confirmed and expanded by additional methods of surveillance. Collecting and analyzing health surveys, poison control center and emergency room admissions data would help determine who is using delta-8-THC products and whether there are any adverse events associated with use. Conducting qualitative studies or analyzing other web data sources such as forums could help uncover how and why individuals are using delta-8-THC products. Analyses of sales channels such as e-commerce, sales records and marketing could

help identify delta-8-THC retailer's and manufacturer's distribution and sales tactics and how these might be appropriately regulated.

While public interest in delta-8-THC appeared concentrated in the US, these findings have broader implications. Already, some delta-8-THC manufacturers have opened offices in Europe—e.g., one manufacturer has offices in the United Kingdom (Just Delta, 2021). Jurisdictions outside the US as well as those within should clarify whether the methods of converting cannabinoids to THC compounds are legal under hemp and cannabis laws. We recommend a public-health-focused approach that clarifies definitions of THC compounds to include delta-8-THC and other THC isomers and disallows the use of methods that convert CBD to THC, at least until these can be determined to be safe (Leas, 2021).

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Ethics approval

The authors declare that the work reported herein did not require ethics approval because it did not involve animal or human participation.

Declarations of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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