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Authors
Roth, Winter
Tam, Mitchell
Bi, Carrie
et al.

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Changes in California cannabis exposures following recreational legalization and the COVID-19 pandemic

Winter Roth[a], Mitchell Tam[a], Carrie Bi[a], June Kim[a], Justin Lewis[b], Raymond Ho[b] and Dorie E. Apollonio[a]

[a]School of Pharmacy, University of California, San Francisco, CA, USA; [b]California Poison Control System, San Francisco, CA, USA

ABSTRACT

Introduction: Since 2012, eighteen states and the District of Columbia have legalized recreational cannabis. Past research suggests this policy change is associated with increased cannabis exposures however this has not yet been studied in California, despite its status as the world's largest legal cannabis market.

Methods: This observational, retrospective study analyzed trends in cannabis exposures reported to the California Poison Control System (CPCS) from 2010 to 2020. We assessed shifts in exposures before and after the legalization of recreational cannabis in November 2016, the establishment of recreational retail sales in January 2018, and the institution of a statewide shelter-in-place order due to the COVID-19 pandemic in March 2020 using interrupted time-series analysis and reviewed all records to identify specific products associated with exposures.

Results: Between 2010 and 2020 edible exposures increased from near zero to 79% of exposures in 2020. Cannabis exposures significantly increased following recreational legalization in 2016 (by an estimated 2.07 exposures per month [CI: 0.60, 3.55]; $p < 0.01$) and initiation of retail sales in 2018 (0.85 [CI: 0.12, 1.58]; $p < 0.05$). There was no significant change in cannabis exposures following the first shelter-in-place order of the COVID-19 pandemic (1.59 [CI: −1.61, 3.68]; $p = 0.43$). Cannabis exposures for those thirteen and under increased significantly both after recreational legalization (1.04 [CI: 0.38, 1.70]) and after the opening of the retail sales market (0.73 [CI: 0.34, 1.12]), but not following the shelter-in-place order (1.59 [CI: −1.61, 3.68]), nor was there a significant change for those older than thirteen.

Conclusions: Our findings suggest that cannabis legalization is linked to increased exposures, particularly for products such as gummies and candy edibles among children under the age of thirteen. Clinicians should be aware of these risks and communicate them to patients, and policymakers should consider stronger regulations on packaging to reduce these exposures.

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Cannabis; marijuana; public health; THC; recreational legalization; California

KEY POINTS

- Question: How have cannabis exposures changed following legalization of recreational use, the opening of the recreational retail sales market, and the institution of shelter-in-place orders during the COVID-19 pandemic?
- Findings: In this retrospective review of 10,757 cases reported to the California Poison Control System (CPCS) between 2010 and 2020, exposures increased significantly after the legalization of recreational cannabis use and the opening of the recreational retail sales market, particularly among children, who primarily consumed candies and gummies.
- Meaning: Stronger regulation of cannabis edibles that mimic other products is warranted to decrease exposures among children.

Introduction

In 1996, California became the first state to legalize the use of medical cannabis [1]. Children's exposures to cannabis increased by a factor of three from 2010 to 2016 [2]. For children under 6 these exposures were primarily accidental; for adolescents these exposures were more commonly related to cannabis misuse [2]. In November 2016, two decades after the medical legalization, Californians passed a ballot measure legalizing recreational cannabis [3].

Recreational cannabis legalization has been associated with increased exposures, and these disproportionately affect vulnerable groups, particularly children, young adults, and older adults [4–6]. As of 2021, eighteen states and the District of Columbia had legalized recreational cannabis and cannabis had been decriminalized in 27 states [7]. In the first two years after recreational legalization in Oregon and Alaska, local poison control centers reported increased accidental cannabis exposures among children, commonly leading to sedation [8,9]. Children were also more likely to be

CONTACT Dorie E. Apollonio dorie.apollonio@ucsf.edu Department of Clinical Pharmacy, University of California, San Francisco, 530 Parnassus Ave Suite 366, San Francisco, 94143, CA, USA

Supplemental data for this article can be accessed here.

admitted to intensive care after exposure [8,10]. After Colorado legalized recreational cannabis in 2012, unintended health consequences included increased healthcare visits due to ingestion, cyclic vomiting syndrome due to frequent use of high THC concentration products, and burns from THC extraction-related explosions (at least 20 of these cases required skin grafting) [11]. Colorado also reported increased healthcare visits due to accidental ingestion of edible products by children and increased unintentional overdoses [11,12], while among adults, concentrated products such as resins and liquid concentrates resulted in increased toxic exposures [9]. In 2013, there had been a 16 percent increase in hospitalizations in Colorado due to cannabis in pediatric patients and a 30 percent annual increase in call rates to poison control [13].

COVID-19 shelter-in-place orders may also have affected cannabis exposures; with increased cannabis use anticipated in response to lockdowns [14]. Mental health stress associated with the COVID-19 pandemic has been associated with increased desire to use recreational substances, especially in states where cannabis is legal [14]. Surveys conducted in April 2020 found that Canadian adolescents aged 14 to 18 years increased their alcohol and cannabis use, and had increased feelings of depression and fear, which are associated with solitary substance use [15].

To our knowledge, no study has examined changes in cannabis exposures in California since recreational legalization in November 2016, the institution of a recreational retail sales market in January 2018, or after the March 2020 statewide shelter-in-place orders intended to reduce the risk of exposure to COVID-19. Past research assessing unintended consequences of cannabis legalizations notes that existing studies are not generalizable to all populations and states [16]; this is particularly relevant for California, which by itself constitutes the world's largest cannabis market [17]. Previous studies of cannabis exposures were completed before the COVID-19 pandemic and failed to capture exposure rates under pandemic conditions. Since Colorado first legalized recreational cannabis use in 2012, other states have followed and also implemented legalization of recreational cannabis [8].

In this study we reviewed cannabis exposures in California, before and after legalization of recreational cannabis use, after the establishment of recreational retail sales, and during the first nine months of the COVID-19 global pandemic. We hypothesized that cannabis exposures would increase significantly following each of these changes, especially among children. We also classified product exposures by type to assess which might be associated with exposures among children, in light of popular media reports that have identified group overdoses among children involving cannabis gummies [18,19].

Methods

Design

This observational, retrospective study analyzed trends in cannabis exposures reported to the California Poison Control System (CPCS) before and after the legalization of recreational cannabis in November 2016, the establishment of recreational retail sales in January 2018, and the institution of a statewide shelter-in-place order due to the COVID-19 pandemic in March 2020.

Data source and collection

CPCS serves California's population of 40 million people, making it the largest poison control provider in the United States. We obtained reports of cannabis exposures from CPCS from January 1, 2010 to December 31, 2020. Inclusion criteria were human exposures to cannabis and cannabis containing products reported within California. Cases were identified by searching the CPCS database for American Association of Poison Control Centers (AAPCC) codes relating to cannabis. We excluded calls from outside California.

Measures

Exposures were defined as an "actual or suspected contact with any substance which has been ingested, inhaled, absorbed, applied to, or injected into the body, regardless of toxicity or clinical manifestation." [20] Case records were individually reviewed by one of four raters (CB, JK, WR, MT) to verify that exposures were actually related to cannabis, to separate human from animal exposure calls, to validate the call involved an exposure rather than a request for information, to check whether exposures involved a single substance (cannabis only) or multiple substances, and to detail the nature of the product involved in each exposure (e.g., candy, secondhand cannabis smoke) given that poison control centers until recently did not classify cannabis exposures beyond "marijuana" and route of exposure (e.g., inhalation, ingestion). Records with unclear classifications were reviewed with three other authors (DA, RH, JL). CPCS records were collected and managed using REDCap, a secure, web-based software platform designed to collect and manage study data [21,22].

Interrater reliability

To assess interrater reliability, we drew a random sample of 200 CPCS cannabis records; two of the four raters coded each to determine whether it met inclusion criteria. We used Gwet's AC1 to calculate interrater reliability, which ranged from 0.963 (for whether the record related to cannabis) to 1.000 (all other classifications) [23,24]. Given these high levels of interrater reliability all subsequent records were assessed for inclusion criteria by a single coder. Before proceeding to individual coding all disagreements between coders were discussed with two assessors not involved with the preliminary coding (DA, RH) until consensus was reached.

Given that AAPCC codes did not necessarily identify product types, raters also listed details of each exposure drawn from the record's comments field. During the validation process, raters and assessors discussed the level of specificity to report until consensus was reached. Raters copied details regarding product type and exposure for each record (e.g., "gummy" rather than "edible"), as well as indicating reported secondhand smoke exposures and listing brand names where provided. Intentional inhalation exposures through smoking were coded by substance name ("marijuana", "THC", "cannabis", etc.). Non-inhalation exposures added product type information where available (e.g., "marijuana *oil*", "THC *edible*", "cannabis *gummy*", etc.). Secondhand smoke exposures were coded as "smoke" (i.e., "marijuana *smoke*").

Our classification of product types used the following guidelines: candy for candy and nonspecific sweets, chocolate for all chocolate products, baked goods for brownies, cookies, and other baked goods, gummies for any gummy product, other edibles for products that did not fit in candy, gummies, or baked goods categories, newer technology for dabs and vapes, traditional products for blunts, joints, hash, and plant products, synthetic for spice, K-2, and any specific synthetic product names, hemp for any product mentioning hemp, and oil for cannabis, THC, and marijuana oils. A complete list of codes in each category is provided in the Supplement.

Analytical strategy

Our analyses relied on interrupted time series analysis to assess changes in exposures at each time point representing a policy intervention: November 2016 (recreational use), January 2018 (retail sales), and March 2020 (the institution of the COVID-19 related shelter-in-place order). The standard ITSA model follows the form $Y_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 X_t T_t + \epsilon_t$, where for a single intervention, β_0 is the intercept, β_1 is the slope prior to intervention, β_2 is the change immediately following the intervention, and β_3 represents the treatment effect of that intervention over time; because these data are represented as monthly counts, reported coefficients represent estimated monthly increases or decreases in reported exposures after the intervention [22]. Multiple group analyses expand the regression model to include additional coefficients that represent differences between groups. We used the "itsa" plug-in for Stata 16 to conduct the analysis, followed by "actest" to test for autocorrelation [25]. Our primary outcome was counts of total monthly cannabis exposures, with expansions for different age groups and routes of exposure. Our analysis of cannabis exposures by product type was descriptive (total exposures aggregated by year) and analytical (testing for significant changes in trends over time using Kendall's tau).

The University of California, San Francisco IRB approved this study as exempt on December 9, 2020 (#20-32966).

Results

CPCS coded 12,108 exposures from January 2010 to December 2020 as cannabis; 1,351 (11%) of these exposures did not meet inclusion criteria, as they were miscoded, involved animals, were calls from outside California, or were requests for information. Of the remaining 10,757 exposures, 20 percent involved someone under the age of six, 6 percent someone between the ages of six and twelve, 24 percent someone between the ages of thirteen and nineteen, and 50 percent an adult (aged 20 years or older). Forty-four percent of exposures were female, and 56 percent were male. Additionally, 79 percent of the exposures involved ingestion, 18 percent involved inhalation, and 3 percent other routes including topical, rectal, parenteral, subcutaneous, or ophthalmic, as shown in Table 1. Although the total population of California grew by an estimated 6.1% from 2010 to 2020, with an increase of 22.5% in those under the age of 18 and a 6% increase in those under 5 years of age [26]; calls to CPCS related to cannabis more than tripled over the same period. The number of cannabis exposure calls in proportion of all incoming calls is described in Table 2.

Among children under the age of six years, 2,130 calls were assigned a code indicating the reason for exposure, of these, 2,107 (98.9%) were coded as unintentional exposures, zero as intentional, and the remaining 23 (1.1%) were coded as other (a category including unknown, malicious, contamination, and adverse reactions). Among children aged six to 12 years, 625 calls were assigned a reason code, and of these 504 (80.4%) were coded as unintentional, 84 (13.4%) as intentional, and the remaining 38 (6.1%) as other.

Our interrupted time series analysis first considered overall changes in exposures after legalization of use, initiation of retail sales, and after the COVID-19 shelter-in-place order. As noted in methods, ITSA coefficients represent estimated monthly increases or decreases in reported exposures after an intervention. Following recreational legalization in 2016, estimated monthly cannabis exposures increased significantly (2.07 exposures per month [CI: 0.60, 3.55]). Following the implementation of retail sales in 2018, cannabis exposures increased significantly as well (0.85 [CI: 0.12, 1.58]). However, no significant change in cannabis exposures was observed following the shelter-in-place order. A graph of exposures over time is provided in Figure 1; detailed estimates are provided in Table 3.

We continued by comparing changes in exposures for two age groups: those under thirteen years old and those thirteen years and older. Age is provided in CPCS records and this categorization follows AAPCC convention; exposures without information on age were excluded. Cannabis exposures in those under thirteen increased significantly both after recreational legalization (1.04 [CI: 0.38, 1.70]) and after the opening of the retail sales market (0.73 [CI: 0.34, 1.12]), but not following the shelter-in-place order (1.59 [CI: −1.61, 3.68]). For those thirteen and older, there was no significant change over time. As a result, although exposures in children under thirteen were the minority in January 2010, by December 2020 they represented nearly half of all exposures, as shown in Figure 2. (Detailed estimates for each age group are provided in the Supplement.)

To assess possible changes in exposures by product type, we organized ingestion exposures (the majority) by product type and grouped these into categories. We identified significant increases over in the number of exposures for gummies (Kendall's tau < 0.001), candies (Kendall's tau < 0.001), chocolate (Kendall's tau < 0.01), dabs (Kendall's tau < 0.01), edibles in the form of drinks (Kendall's tau < 0.05), hemp

Table 1. Total cannabis exposures by age and route.

	Ages < 6	Age 6 to 12	Age 13 to 19	Age 20 and above	Total # of Exposures
# of individuals exposed	2152 (20.0)	646 (6.0)	2581 (23.9)	5378 (49.9)	10,757
	Ingestion	Inhalation	Topical, rectal, parental, subcutaneous, ophthalmic		
Route of exposure	8497 (78.9)	1931 (17.9)	329 (3.1)		10,757

Table 2. Total number of calls to CPCS compared to number of cannabis-related calls by year.

Year	Total number of calls to CPCS	Number of cannabis-related calls to CPCS	Percent of cannabis-related calls (%)
2010	227,062	646	0.28
2011	229,804	847	0.37
2012	228,588	727	0.32
2013	224,250	675	0.30
2014	227,678	759	0.33
2015	223,876	872	0.39
2016	221,737	932	0.42
2017	217,590	1,279	0.59
2018	217,524	1,613	0.74
2019	224,613	1,684	0.75
2020	222,133	2,084	0.94

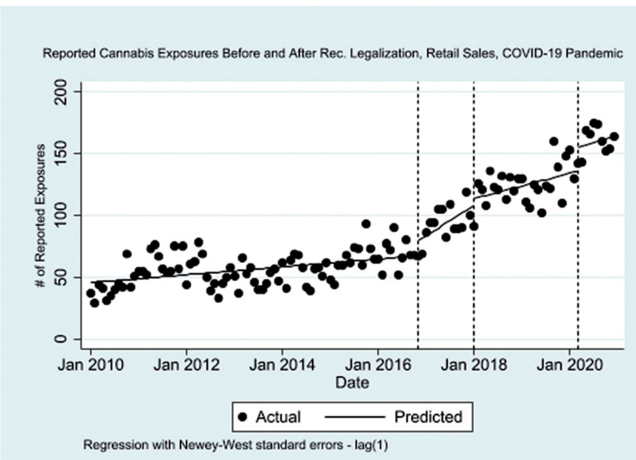

Figure 1. Interrupted time series analysis of California cannabis exposures from January 2010 to December 2020 for three policy interventions; legalization of recreational use in November 2016, opening a recreational retail sales market in January 2018, and COVID-19 shelter-in-place order in March 2020.

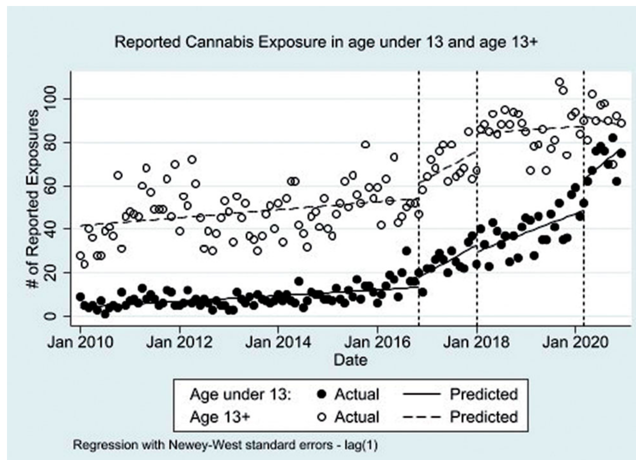

Figure 2. Interrupted time series analysis of monthly exposures from January 2010 to December 2020 for three policy interventions; legalization of recreational use in November 2016, opening a recreational retail sales market in January 2018, and COVID-19 shelter-in-place order in March 2020, by age.

Table 3. Interrupted time series coefficients and confidence intervals for cannabis exposure trend lines before and after policy changes.

	Coefficient	Confidence Interval	
	Pre-recreational legalization		
Cannabis exposure	0.27	0.14, 0.39	
	Post-recreational legalization		*p* Value
Cannabis exposure	2.07	0.60, 3.55	<0.01
	Post-retail sale initiation		
Cannabis exposure	0.85	0.12, 1.58	<0.05
	Post-COVID shelter-in-place order		
Cannabis exposure	1.04	−1.61, 3.68	0.43

(Kendall's tau < 0.01), joints (Kendall's tau < 0.01), blunts (Kendall's tau < 0.05), cannabis oils (Kendall's tau < 0.01), vapes (Kendall's tau < 0.001), other edible products (Kendall's tau < 0.001), and all other products (Kendall's tau < 0.001) between 2010 and 2020. However, there was no change in the trend of exposures for cookies, brownies, other edible baked goods, hash, plant products, or synthetic products.

We aggregated these categories into nine broad product types: (1) chocolate and candy, (2) other edibles and drinks, (3) gummies, (4) brownies, cookies, and other baked goods, (5) new technology (dabs and vapes), (6) traditional products (joints, blunts, etc.), (7) oils, (8) hemp products, and (9) synthetics, then graphed exposures (Figure 3). Chocolate and candy, other edibles and drinks, and gummies increased from levels near zero prior to recreational legalization to thousands of exposures per year by 2020. For example, there were only 16 total reported gummies exposures in the six years between 2010 and 2015; these increased to 409 exposures in 2020 alone.

Discussion

We analyzed trends in cannabis exposures reported to the CPCS before and after the legalization of recreational cannabis in November 2016, the establishment of recreational retail sales in January 2018, and the institution of a statewide shelter-in-place order due to the COVID-19 pandemic in March 2020 and found that as expected, exposures increased following recreational legalization and the establishment of retail sales, consistent with previous studies [4,11]. However

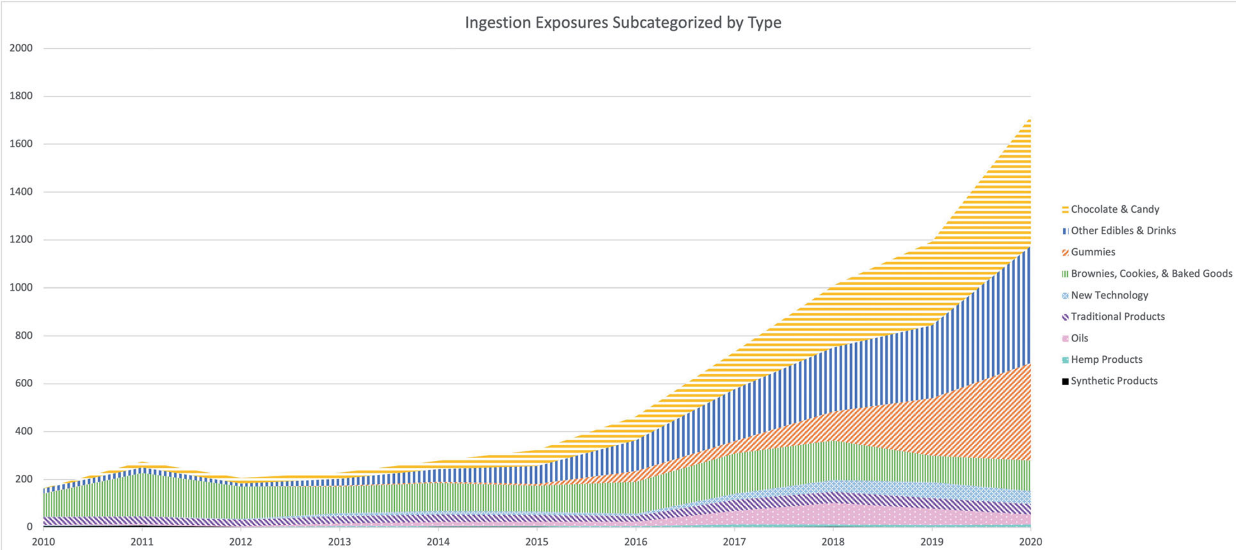

Figure 3. Aggregated exposures by cannabis product type, 2010-2020, representing each year's total exposures.

despite expectations we did not find a significant change in cannabis consumption following the COVID-19 shelter-in-place order [12,13]. This finding may reflect that only nine months of exposure cases following March 2020 were available at the time of this study. We also found that cannabis exposures in children under thirteen increased significantly following recreational legalization and initiation of retail sales but did not increase for teens and adults. As a result, although cannabis exposures were uncommon among young children in 2010, by 2020 they constituted nearly half of all exposures.

Ingestion and inhalation were the most common routes of exposure. Cannabis edibles such as gummies, candy, and other dessert-like products have been involved with increased use in younger users (including youth under grade 12) [27]. Our detailed records review found that a common exposure after 2018 involved a child or group of children finding cannabis edibles that they perceived to be normal candy and consuming an entire package. Particularly among the youngest children (under six) the primary reason for exposure was accidental ingestion, in which children or their caregivers mistakenly identified cannabis gummies as ordinary candy.

Cases in which cannabis gummies and other edibles are mistaken for non-cannabis products may result from issues with packaging [28]. Although California regulates the potency of cannabis edibles and requires opaque, resealable packaging, each edible (e.g., a single gummy) can contain up to 10 mg of THC and each package up to 100 mg of THC; as a result, even a single gummy represents a high dosage for a naïve user, particularly a child [29,30]. By comparison, edible regulations in Canada, for example, place a limit of 10 mg of THC per package, even if it the package contains multiple edibles, as well as requiring plain packaging and larger warning labels [31]. As a result, a child who accidently consumed an entire bag of cannabis gummies in Canada would likely be exposed to the same level of THC as one who consumed a single gummy in California. We note that Canadian regulations on packaging were instituted in 2020, so there is limited data to assess potential changes in pediatric exposures after this policy change. However, given reported confusion among both children and caregivers about whether candy products contain cannabis, instituting similar regulations such as plain packaging and lower doses per edible, or expanding on them by requiring individual packaging, offer potential for reducing the high levels of exposures among children.

Our study has limitations. The data were drawn from a single state, limiting potential generalizability; however, California's status as the most populous with the largest cannabis market allows us to assess trends that would not be possible in smaller areas. Moreover, the more granular data provided by CPCS made it possible to classify product types; these data are not available at the national level. Using poison control data only captures data volunteered by patients and providers and these may not capture general patterns of use. In addition, although CPCS seeks to create a case report linked to individuals rather than to group exposures, in some cases, multiple exposures were reported in a single record (e.g., a call regarding multiple children exposed to cannabis in school). As a result, these findings are likely to be underestimates of actual exposures. Our classification of product types was limited by reporters, who may use a range of terms to describe cannabis products (for example, exposure to THC oil could mean either vaping or cooking food in cannabis oil); as a result, we were unable to categorize all exposures and may have failed to identify additional products associated with exposures. Finally, given that the study was observational in nature, we could only identify associations between cannabis exposures and policy interventions rather than establishing causality. Despite these limitations, the absence of other contemporaneous factors expected to increase exposures, as well as the consistency of these findings with prior research, suggest that recreational legalization and sales were associated with significant increases in exposures, particularly among children.

Conclusions

We hypothesized that cannabis exposures would increase significantly following recreational legalization and during COVID-19, especially among children, and found that recreational cannabis policies were associated with significant increases that were driven by exposures among children. By 2020, most of these increased exposures involved dessert-like products that are easily confused with products that do not contain cannabis such as gummies, other candies, and chocolate. Exposures to these products increased significantly between 2010 and 2020. These findings suggest that policymakers should consider regulatory changes for cannabis products such as reduced dosing per package size or individual packaging [32]. They also suggest a critical need for stronger public health protections relating to cannabis as more states implement recreational legalization [33,34]. In the absence of such policies, our findings provide new information regarding the risk of pediatric cannabis exposures and offer guidance to clinicians to assess cannabis use, particularly for caregivers, and to encourage safer storage of these products [35,36].

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Ethical approval and protection of human participants

The University of California, San Francisco Institutional Review Board approved this study as exempt on December 9, 2020 (#20-32966).

Author contributions

Winter Roth: Conceptualization; Methodology; Validation; Formal analysis; Investigation; Writing-original draft; Writing-review and editing; Visualization. Mitchell Tam: Conceptualization; Methodology; Validation; Formal analysis; Investigation; Writing-original draft; Writing-review and editing; Visualization. Carrie Bi: Conceptualization; Methodology; Validation; Formal analysis; Investigation; Writing-original draft; Writing-review and editing; Visualization. June Kim: Conceptualization; Methodology; Validation; Formal analysis; Investigation; Writing-original draft; Writing-review and editing; Visualization. Justin Lewis: Conceptualization; Methodology; Validation; Resources; Data curation; Writing-review and editing; Supervision. Raymond Ho: Conceptualization; Methodology; Validation; Resources; Data curation; Writing-review and editing; Supervision. Dorie E. Apollonio: Conceptualization; Methodology; Validation; Formal analysis; Data curation; Writing-original draft; Writing-review and editing; Visualization; Supervision; Project administration; Funding acquisition.

Disclosure statement

The authors declare they have no actual or potential competing financial interests.

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ORCID

Dorie E. Apollonio http://orcid.org/0000-0003-4694-0826

Data availability statement

Data for replication can be obtained by submitting a Data Request Form to the California Poison Control System.

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