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RESEARCH REPORT

Young adult retail purchases of cannabis, product category preferences and sales trends in California 2018–21: Differences compared with older adults

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Abstract

Aims: The aim of this study is to identify cannabis products according to their appeal among young adults and measure product sales trends.

Design, setting and participants: This was a retrospective comparative study using point-of-sale data from licensed recreational cannabis retailers that include buyer age with birth year entered by retailers, set in California, USA. Cannabis purchases by young adults (aged 21–24, GenZ) were compared with older adults (age 25+) over 4 years (2018–21).

Measurements: Sales for six cannabis product categories were analyzed using a commercial data set with imputations and a raw data set. Age-appeal metrics were dollar and unit sales to young adults, and dollar and unit share ratios (young adults/older adults), where a share ratio of 100 denotes age-appeal comparability. A product category was considered more young-adult appealing than others if its mean on a metric was at least one standard deviation above the grand mean across all product categories.

Findings: Flower (cannabis plant material) and vapor pen appealed to young adults based on absolute dollar sales, dominating young-adult spending compared with other cannabis products (37.24 and 31.83%, respectively). Vapor pen and concentrate appealed to young adults based on dollar share ratios of 152, meaning these products comprised a 52% greater share of young-adult cannabis spending relative to older-adult spending (31.83/20.97% and 10.47/6.88%, respectively). Less appealing to young adults were pre-roll, edible/beverage and absorbable products (tincture/sublingual, capsule and topical). Flower showed the largest dollar sales growth (B = +$3.50 million/month), next to vapor pen (B = +$1.55 million/month). Vapor pen tied for highest growth in the percent of product dollars from the largest package size (B = +0.85%/month) and showed the steepest price decline (B = −0.53 price per gram/month).

Conclusions: In California, USA, from 2018 to 2021, relative to older adults, young adults spent a greater share of their cannabis dollars on vapor pen and concentrate (products with high potency of delta-9-tetrahydrocannabinol).

KEYWORDS
Cannabis, marijuana, retail, retail sales, weed, young adults

INTRODUCTION

Identifying tobacco and alcohol product types and marketing that appeal to young people has led to important public health protections. After Camel cigarettes started using advertisements with cartoons [1], the US Master Settlement Agreement prohibited this tactic [2]. Following the discovery that JUUL-flavored cartridge-based e-cigarettes appealed to young people [3], the US Food and Drug Administration (FDA) banned products of this type with youth-appealing flavors [4]. In a similar vein, specific cannabis products such as inhaled concentrates with high concentrations of tetrahydrocannabinol (THC), especially if marketed with youth-appealing features, may attract adolescent and young-adult consumers, increasing the importance of identifying policies that will limit problematic market-place practices [5, 6]. High THC potency has been associated with an increased risk of cannabis use disorder and psychosis [7]. The combination of increasing levels of potency [8] and mass commercialization of cannabis [9] may account for the striking rise in cannabis use, the tripling of daily use and the rise of cannabis use disorders among young adults [7, 10, 11]. Unlike teens, young adults can legally purchase cannabis in nearly half the United States, but like teens, their brains are still maturing and they are in a peak period for developing psychosis and schizophrenia, whose incidence appears to be associated with cannabis use [12]. Thus, policymakers should prioritize the protection of young adults as well as adolescents.

California State cannabis regulation has not been exemplary in its protection of youth and young adults. State regulations are relatively lenient, and few local jurisdictions have exerted their right to more rigorously regulate product offerings (e.g. edibles imitating existing brands or flavored vapor pens) [13]. This raises the concern that more hazardous product offerings may grow in popularity, as they remain largely unregulated. For example, vapor pen (a battery device with a heating element and a cartridge containing liquid cannabis concentrate) has gained market share and undergone the most pronounced increase in tetrahydrocannabinol (THC) potency among the cannabis product categories studied in Washington State [14]. This trend is reason for concern that legalizing sales for recreational use may be associated with substantial increases in cannabis potency [5].

A pressing issue is whether young adults versus older adults disproportionately purchase cannabis products with higher potency or other specific characteristics posing greater risk. One recent study reported that vapor pen was the second most popular cannabis product category, surpassed only by flower, among 16–20-year-old cannabis users in the United States, regardless of whether or not their state had legalized recreational cannabis sales [6]. In states that legalized cannabis sales, among 16–20-year old users past-week use prevalence was 28.4% for cannabis flower, 19.4% for vapor pen, 10.6% for concentrate and 6.8% for edible [6].

Population surveys have long been used to monitor drug use by age. The US Monitoring the Future survey reports that in 2022 among young adults aged 23–24 years, past-30-day use prevalence was 32.9% for any cannabis and 16.5% for cannabis vapes [11]. While such surveys are crucial for public health monitoring and planning, they do not provide detailed measures such as purchase amounts, prices paid or THC levels. Cannabis retail purchase data from marketing research firms are a promising data source from which purchase amounts by specific product type and buyer age can be estimated for legal markets [15, 16]. In addition to these commercial databases, many US states have track-and-trace systems for monitoring cannabis sales, and in some states the anonymized data are shared with researchers [5, 14].

We provide the first look at recreational (adult-use or non-medical) cannabis retail sales in California, and sales by age group. Aim 1a identified cannabis products according to their appeal to young adults using a widely available commercial data set. Aim 1b determined if the Aim 1a results replicate in a raw data set without the imputations used in the commercial data set to address missing or incomplete data. Aim 2 identified sales trends for products according to their appeal to young adults. Our overall goal was to identify cannabis products attractive to young adults to help inform regulation that may be needed to protect this vulnerable group.

METHODS

Buyer age

Based on the available retail data, young adults in this study are defined as GenZ, born 1997–2000, making them 21–24 years of age when their cannabis purchases were recorded. Older adults are from older generations, born before 1997, making them age 25 or older when their cannabis purchases were recorded.

Data set for Aims 1a and 2: California state-wide sales

For Aims 1a and 2, we use a commercially available data set of recreational (non-medical) cannabis retail sales in California from the company Headset. Headset recruits representative samples of licensed recreational cannabis retailers in the United States and Canada and obtains real-time sales data. With a one-year license to Headset's Premium Insights data set for California, we obtain sales by buyer generation for 2 years (2020–21) and sales without buyer generation for 4 years commencing with recreational sales legalization in the state (2018–21; Table 1).

California state-wide sales are imputed based on Headset's retail sample. Its retail sample currently includes about 450 licensed

TABLE 1 Data set description by aim.

	Aim 1a	Aim 1b	Aim 2
Research aim	Assess appeal by age	Verify appeal by age	Identify sales trends
Data set provider	Headset	Headset	Headset
Data set scope	CA state-wide data	CA raw retail data	CA state-wide data
Data set name	Premium Insights	Custom data pull	Premium Insights
Data set access	Wide availability	Negotiated once	Wide availability
Missing sales in state	Imputed	Missing	Imputed
Years available	2020–21	2018–21	2018–21
Age data provided	Generation	Birth year	NA
Focal measures	Dollar, unit sales	Dollar, unit sales	Sales by size, price, promo
Unknown package sizes	NA	NA	Imputed
Product subcategories	71	83 (71 + miscellaneous)	71
Unknown subcategories	Imputed	Missing	Imputed
Young adult definition	GenZ born 1997–2000	GenZ born 1997–2000	NA
Young adult age range	Aged 21–24	Aged 21–24	NA
Missing ages	Imputed	Missing	NA

Note: A Premium Insights subscription gives data set access for a specified time: for example, 1 year. The Headset age data by generation is discussed at: https://www.headset.io/industry-reports/demographics-report-2023; it includes GenG (aged 11–26, as of this report), millennials (aged 27–42), GenX (aged 43–58) and baby boomers (aged 59–77). The product categories and subcategories (called segments) are discussed at: https://help.headset.io/kb/article/32-headset-s-standardized-categories-segments/. The imputations used to attain state-wide sales and identify unknown product subcategories and package sizes are discussed in: https://help.headset.io/kb/article/11-insights-quick-start-guide/, https://help.headset.io/kb/article/120-insights-sampling-process-analytical-methods/ and https://www.headset.io/training/navigating-market-trends-with-headset-insights-a-focus-on-the-california-cannabis-industry. In the raw data set, the miscellaneous subcategories are unknown (n = 9), flower seed, vapor pen live resin and beverage gummy.
Abbreviations: CA, California; NA, not applicable.

retailers, representing urban, suburban and rural geographies across the state that are multi-store operators, large single stores or other store sizes. When imputing state-wide sales from its retail sample, Headset has verified that its methods produce state-wide sales estimates that closely mirror sales reflected in the gross retail receipts submitted to the CA Department of Cannabis Control for purposes of paying the cannabis excise tax. When a retailer is part of the Headset retail sample, each sale registers the product sold based on its name, which is associated with a package size and product category and subcategory either automatically or through human coding. To determine sales by buyer generation, Headset uses buyer birthdates entered into its inventory system at retailer discretion, typically for loyalty programs. Missing generational sales are imputed based on observed sales by scaling up. For instance, if Generation Z (GenZ) comprises X% of flower sales when generation is known, GenZ is assumed to comprise that same X% of flower sales overall.

The six product categories in our study are flower (cannabis plant material), vapor pen (battery device with heating element plus cartridge with liquid cannabis concentrate), edible/beverage (cannabis-infused food or drink), pre-roll (cannabis plant material manufactured into a joint), concentrate (inhalable cannabis extracted for higher potency) and what we will call an absorbable product (a cannabis-infused tincture/sublingual or capsule for oral use or a cream or oil for topical use), one that is absorbed by melting it in the mouth or on the skin.

For Aim 1a, identification of cannabis products according to their appeal to young adults, we use data from 2020 to 2021 on sales by generation. We use the same data set for Aim 2, identification of product trends. However, having already identified age-related product appeal, we no longer require sales by generation; thus, for Aim 2 we utilize the full 4-year commercial data set. We compare trends in product categories with more versus less appeal to young adults (GenZ), monthly from 2018 to 2021.

Data set for Aim 1b: California raw retail sales

In Aim 1b, we seek to verify our Aim 1a findings on age-related product appeal using Headset's raw retail data for 2018–21, obtained through a custom data pull. As we cannot verify Headset's proprietary data imputations, we want to examine whether the raw data patterns mirror those in the imputed data set. Missing data due to non-sampled retailers, non-recorded buyer birth years, or unrecognized subcategories or package sizes remain missing; they are not imputed in this raw data set (Table 1).

The Aim 1b raw data set covers a sizable proportion of recreational retail sales of cannabis in California in 2018 (17.6%), 2019 (19.9%), 2020 (24.3%) and 2021 (27.2%). We again focus on younger adults (GenZ) versus older adults, which we determine using buyer birth years recorded by retailers. We subtract buyer birth year from calendar year of purchase to identify sales to GenZ (born 1997–2000,

aged 21–24) and older generations (born before 1997, aged 25+). Sales with missing birth years decline from 65.77% of dollars in 2018 to 48.06% in 2019, 21.09% in 2020 and 22.11% in 2021, for example, due to expansion of retailer loyalty programs.

Analyses to identify product appeal by age

Researchers have classified as youth-appealing any tobacco brand with 5%+ absolute market share among youth [17]. However, it has been argued that relative market share, or comparing sales to two or more age groups, is an even stronger indicator of age-related appeal [18, 19]. We combine both recommended approaches. First, we consider relative share, or what we call the share ratio, considering (a) how much of the product young adults purchase compared to their total cannabis purchases, versus (b) how much of the product older adults purchase compared to their total cannabis purchases. A share ratio above 100 indicates a product's share is higher among young versus older adults, and thus it is relatively more appealing to young adults. A ratio below 100 indicates the opposite. We calculate share ratios in both dollars and units, as dollars are the standard retail metric [5, 16], but units (i.e. packages or items, not standardized by size or weight in our data set) may capture the appeal of single or low-cost items. Standardized units generally are not available for cannabis yet, as the products themselves are not adequately standardized.

$$\text{Young adult \$ share ratio} = \frac{(\text{dollar purchases of product, young adults})/(\text{total dollars, young adults})}{(\text{dollar purchases of product, older adults})/(\text{total dollars, older adults})} \times 100$$

$$\text{Young adult unit share ratio} = \frac{(\text{unit purchases of product, young adults})/(\text{total units, young adults})}{(\text{unit purchases of product, older adults})/(\text{total units, older adults})} \times 100$$

We also consider absolute sales to young adults in dollar and units because, if they purchase large amounts of it, the product is appealing to them, irrespective of any differential age preference [18, 19]. For instance, cannabis flower is the most frequently purchased cannabis product among all ages in the United States [14, 20], including young adults who may use it in bongs and joints [21, 22], and seek low-cost intoxication [14, 23]. Based on high sales of flower to young adults they find the product appealing, although older adults do also. Our absolute metrics are shown below.

$$\text{Young adult dollar sales} = \Sigma_{\text{time}}\,(\text{dollar purchases of product, young adults})$$

$$\text{Young adult unit sales} = \Sigma_{\text{time}}\,(\text{unit purchases of product, young adults})$$

In sum, our absolute metric indicates what products young people purchase the most, while our relative metric indicates what products young adults purchase disproportionately more than older adults. We classify a cannabis product category or subcategory as appealing to young adults if its mean on one or more metric is at least one standard deviation about the grand mean, across all categories or subcategories, for the focal time period. In marketing research, it is standard practice to use the criterion of one or more standard deviations about the mean to connote high sales, share or other high values [24].

Measures and analyses of trends

Aim 2 assesses trends in price, promotion and package size for product categories according to their appeal to young-adult Californians. As price measurement varies by category, we use unit price/gram of weight for flower, vapor pen, concentrate and pre-roll and unit price/THC in milligrams for edible/beverage and absorbable products. Prices are pre-tax but post-promotion; that is, after discounts are deducted but before taxes. Promotional discounts are listed on the sales receipt as with regular retail sales. To assess the percentage of dollars sold on promotion, we divide dollar sales of the product when purchased on promotion by its total dollar sales (e.g. \$1 M is purchased on promotion versus \$2 M is purchased in total = 50%). To assess percentage of product dollars from the largest package size, we determine the largest package size if recorded (unrecorded ranges from 0.5% for concentrate to 26% for absorbable products). For each product category, we divide dollar sales of the product from the largest package size by its total dollars sales to gain the percentage of sales from the largest package size.

Trends are assessed based on 4-week 'monthly' periods for all measures except percentage of product dollars from promotion where only calendar months are available. We use linear regression with time (month) predicting dollar and unit sales, average price, percentage of product dollars from promotion and percentage of product dollars from the largest package size. We report unstandardized B coefficients reflecting monthly changes in the observed (raw) measures. This research was not pre-registered. The results should be considered exploratory.

RESULTS

Identification of cannabis products with more versus less appeal to young adults (Aim 1a)

It is estimated that nearly \$10 billion in sales transpire at licensed recreational cannabis retailers in California state-wide in 2020 and 2021. By 2021, 13.76% of dollar sales are to young adults (GenZ, aged 21–24; Supporting information, Appendix S1). The findings indicate flower appeals to young adults based on absolute dollar sales (\$463 M) and unit sales (13.58 M), while vapor pen appeals to young adults based on absolute dollar sales (\$395 M) but not unit sales (11.42) (Table 2 and Figure 1). Overall, young adults spend the most

TABLE 2 Cannabis product categories with more versus less appeal to young adults (GenZ, aged 21–24) based on California state-wide and raw retail data sets (Aim 1a, 1b).

	Product category	Sales: young adult	Sales: older adult	Share: young adult	Share: older adult	Share ratio: young adult
State-wide dollars (millions, imputed) 2020–21	**Flower**	**$462.60**	$3849.81	37.24%	44.09%	84
	Vapor pen	**$395.38**	$1830.71	31.83%	20.97%	**152**
	Concentrate	$130.02	$600.42	10.47%	6.88%	**152**
	Pre-roll	$153.77	$1000.12	12.38%	11.45%	108
	Edible/beverage	$82.74	$1066.38	6.66%	12.21%	55
	Absorbable	$17.64	$384.45	1.42%	4.40%	32
State-wide units (millions, imputed) 2020–21	**Flower**	**13.58**	107.55	29.49%	33.79%	87
	Vapor pen	11.42	50.80	24.80%	15.96%	**155**
	Concentrate	4.41	20.37	9.58%	6.40%	**150**
	Pre-roll	10.63	63.11	23.08%	19.83%	116
	Edible/beverage	5.50	66.70	11.94%	20.95%	57
	Absorbable	0.51	9.80	1.11%	3.08%	36
Raw dollars (millions) 2018–21	**Flower**	**$69.92**	$976.53	36.50%	42.82%	85
	Vapor pen	**$63.05**	$516.35	32.91%	22.64%	**145**
	Concentrate	$19.37	$152.96	10.11%	6.71%	**151**
	Pre-roll	$23.72	$252.12	12.38%	11.06%	112
	Edible/beverage	$12.71	$273.64	6.63%	12.00%	55
	Absorbable	$2.81	$108.89	1.47%	4.77%	31
Raw units (millions) 2018–21	**Flower**	**2.07**	28.16	28.40%	32.86%	86
	Vapor pen	1.84	14.42	25.24%	16.83%	**150**
	Concentrate	0.67	5.31	9.19%	6.20%	**148**
	Pre-roll	1.75	17.38	24.01%	20.28%	118
	Edible/beverage	0.87	17.52	11.93%	20.45%	58
	Absorbable	0.09	2.90	1.23%	3.38%	36

Note: Bold type indicates young adults ≥ mean +1 standard deviation (SD) for state-wide dollar sales (mean = 207.03, SD = 163.75), dollar share ratio (mean = 97, SD = 45), unit sales (mean = 7.68, SD = 4.55) or unit share ratio (mean = 100, SD = 45). Similarly, for raw dollar sales (mean = 31.93, SD = 25.35), dollar share ratio (mean = 97, SD = 44), unit sales (mean = 1.22, SD = 0.72) or unit share ratio (mean = 99, SD = 43). Share ratio = (% for young adults/% for older adults) × 100. The six product categories are included in calculating mean and SD. Absorbable includes tincture/sublingual, capsule and topical.

on flower, which comprises 37.24% of their dollar spending on cannabis, followed by vapor pen at 31.83%. This order of preference is also observed for older adults (44.09% flower, 20.97% vapor pen). Considering how young adults spend their cannabis dollars relative to older adults (young/older with 100 = age comparable), both vapor pen and concentrate have dollar share ratios of 152. In other words, these products comprise a 52% greater share of cannabis spending by young adults compared to older adults (31.83/20.97% for vapor pen, 10.47/6.88% for concentrate). Flower's young-adult share ratio of 84 indicates that young adults devote less of their cannabis spending to flower compared to older adults (37.24/44.09%).

Comparable results are found when 2020 and 2021 are examined separately (Supporting information, Appendix S2). Young adult (GenZ) dollar sales are high for flower and vapor pens, whereas unit sales are high for flower only. Share ratios are high for vapor pen and concentrate. Product subcategory analysis yields related results (Supporting information, Appendices S3–S4). Among young adults, flower hybrid and indica have high dollar sales; flower hybrid has high unit sales; vapor pen cartridge has high dollar and unit sales and share ratios; and the concentrates live resin, wax and rosin have high share ratios. Pre-roll connoisseur, pre-roll hybrid single and edible gummy have high unit sales.

Verification of cannabis products with more versus less appeal to young adults (Aim 1b)

The raw retail data set for California captures nearly $2.5 billion in cannabis sales from 2018 to 2021, with 9.90% sold to young adults by 2021 (GenZ, aged 21–24; Supporting information, Appendix S5). Results closely replicate the Aim 1a findings (Table 2 and Figure 2). Flower appeals to young adults based on absolute dollar sales to them ($70 M, 36.50%) as well as unit sales (2.07 M, 28.40%), while vapor pen appeals to young adults based on absolute dollar sales to them ($63 M, 32.91%) but not unit sales (1.84 M, 25.24%). Moreover, compared to older adults, vapor pen and concentrate make up

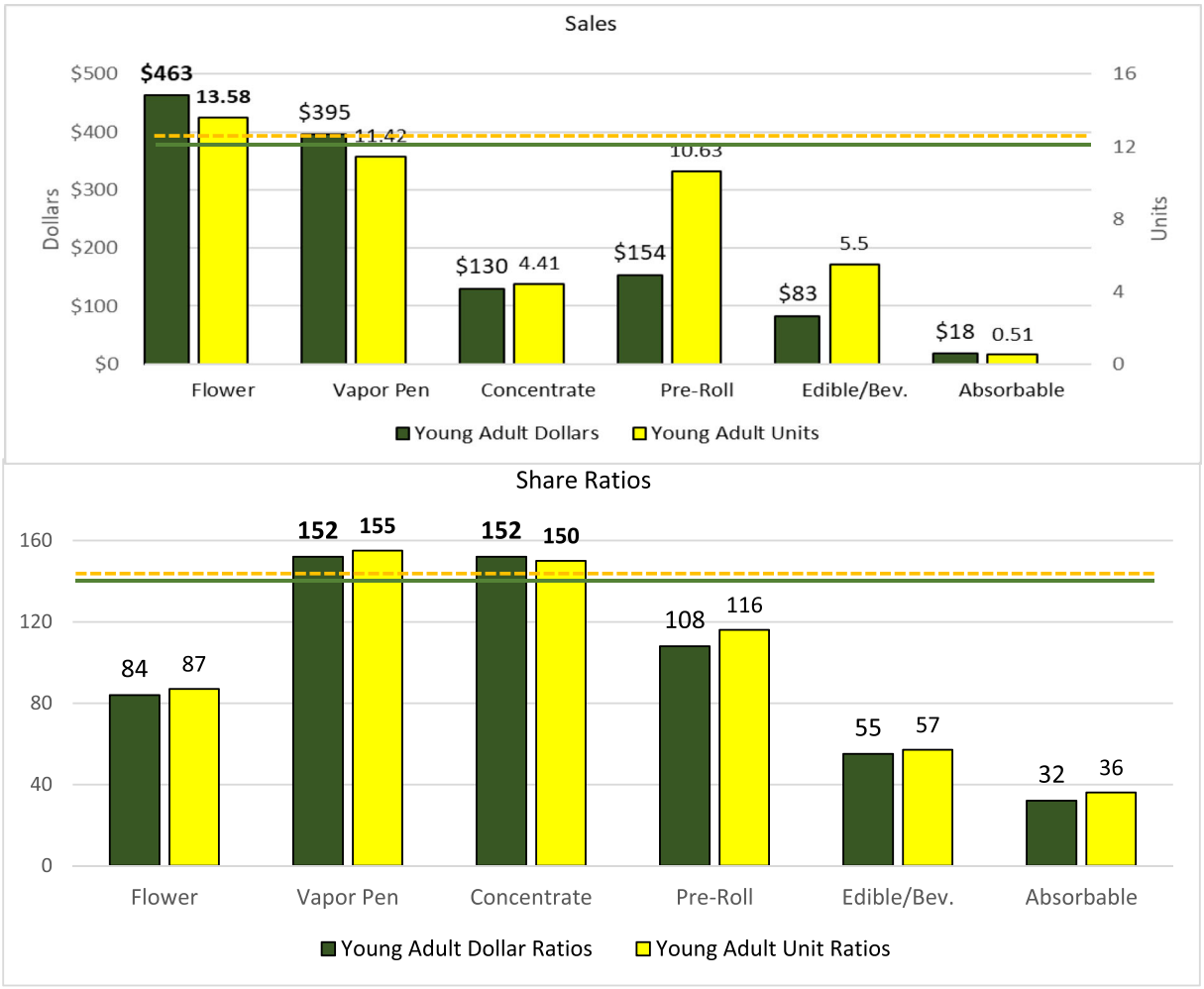

FIGURE 1 Cannabis product categories with more versus less appeal to young adults (GenZ, aged 21–24) based on California state-wide sales (in millions) and share ratios 2020–21 (Aim 1a). Solid line indicates where young adults ≥ mean +1 standard deviation (SD) for dollar sales (mean = 207.03, SD = 163.75) and dollar share ratios (mean = 97, SD = 45); dotted line for unit sales (mean = 7.68, SD = 4.55) and unit share ratios (mean = 100, SD = 45). Share ratio = (% for young adults/% for older adults) × 100. The six product categories are included in calculating mean and SD. Absorbable includes tincture/sublingual, capsule and topical.

a larger share of young-adult cannabis purchases, based on dollar share ratios of 145 and 151, and unit share ratios of 150 and 148, respectively, for these products.

Comparable results are obtained by year from 2018 to 2021 (Supporting information, Appendix S6). Among young adults, flower has high dollar and unit sales all 4 years; vapor pen has high dollar sales all 4 years and high share ratios starting in 2020; and concentrate has high dollar share ratios all 4 years and high unit share ratios except 2021. Results by product subcategory are also generally comparable (Supporting information, Appendices S4 and S7). Among young adults, flower hybrid has high dollar and unit sales; vapor pen cartridge has high dollar sales, unit sales and share ratios; and concentrate live resin has high share ratios. Pre-roll connoisseur has high unit sales and share ratios, and pre-roll hybrid single and edible gummy have high unit sales.

Trends in cannabis products with more versus less appeal to young adults (Aim 2)

For Aim 2, we report raw (unstandardized) monthly changes in sales trends from 2018 to 2021 (Table 3, Supporting information, Appendix S8). Flower, which appeals to young adults based on absolute sales, shows the largest dollar sales growth over the 4 years (B = +$3.50 million/month). Vapor pen, which appeals to young adults based on both absolute sales and relative share ratios, exhibits the second largest dollar sales growth (B = +$1.55 million/month). Vapor pen ties for highest growth in the percentage of product dollars from the largest package size (B = +0.85%/month) with absorbable products (B = +0.93%/month). Four product categories show price declines (excluding pre-roll and edible/beverage), but vapor pen shows the steepest decline (B = −0.53 price per gram/month). Regarding unit sales and the percentage of product dollars

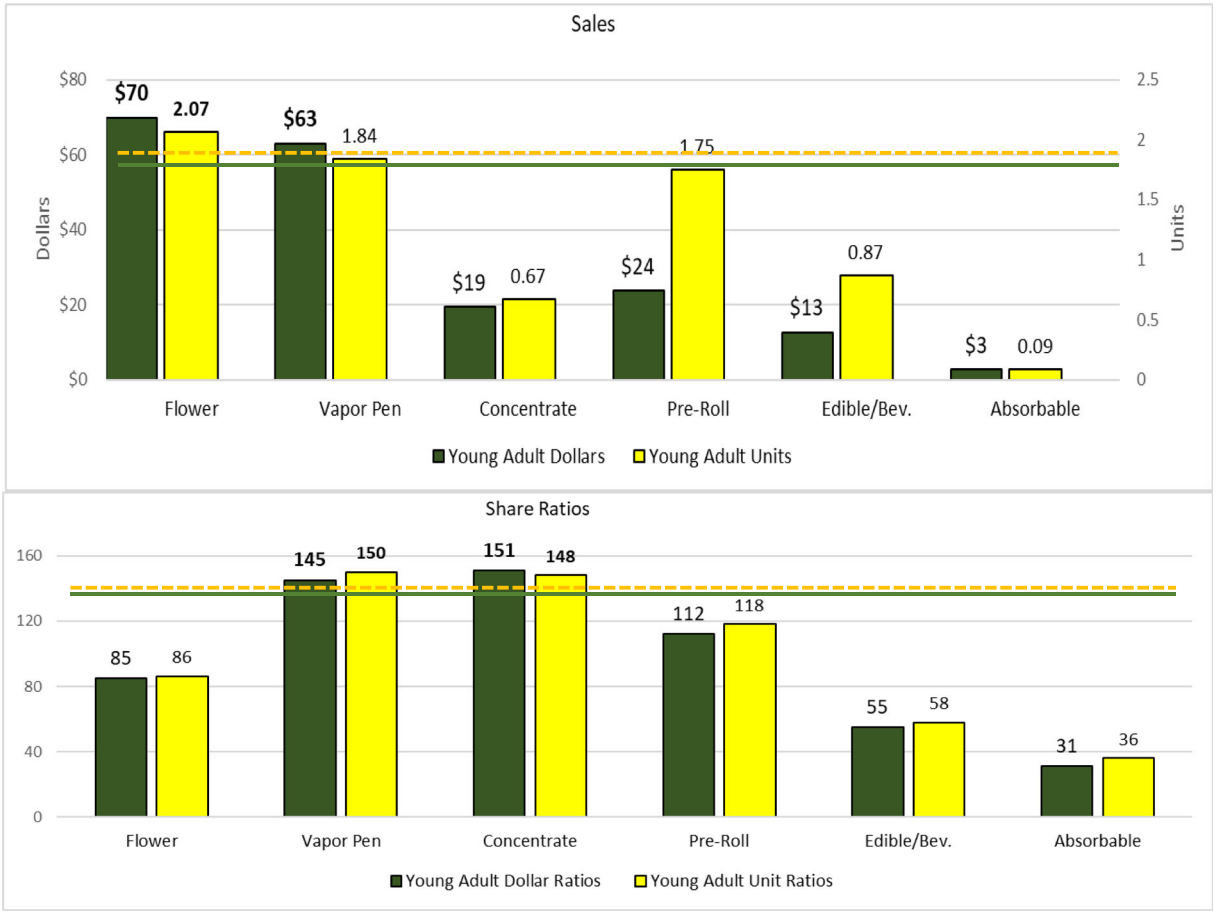

FIGURE 2 Cannabis product categories with more versus less appeal to young adults (GenZ, aged 21–24) based on California raw retail sales (in millions) and share ratios 2018–21 (Aim 1b). Solid line indicates where young adults ≥ mean +1 standard deviation (SD) for dollar sales (mean = 31.93, SD = 25.35) and dollar share ratios (mean = 97, SD = 44); dotted line for unit sales (mean = 1.22, SD = 0.72) and unit share ratios (mean = 99, SD = 43). Share ratio = (% for young adults/% for older adults) × 100. The six product categories are included in calculating mean and SD. Absorbable includes tincture/sublingual, capsule and topical.

TABLE 3 Trends in product categories with more versus less appeal to young adults in California 2018–21 (Aim 2).

	More appeal to young adults			Less appeal to young adults		
	Flower	Vapor pen	Concentrate	Pre-roll	Edible/beverage	Absorbable
Dollars (in millions)	3.50* (18.18)	1.55* (36.01)	0.63* (23.24)	1.15* (43.04)	0.89* (35.44)	0.20* (9.52)
Units (in millions)	0.09* (21.23)	0.05* (47.76)	0.02* (26.32)	0.07* (35.05)	0.06* (33.98)	0.01* (11.93)
% Product dollars from promotion	0.10* (10.67)	0.10* (10.24)	0.08* (5.29)	0.04* (3.76)	0.09* (6.86)	0.11* (14.58)
% Product dollars from largest size	0.35* (17.54)	0.85* (29.53)	0.68* (22.11)	0.66* (12.45)	0.15* (16.2)	0.93* (36.06)
Price/gram or price/THC	−0.05* (8.20)	−0.53* (28.43)	−0.10* (3.99)	0.01* (3.78)	0.0001 (0.90)	−0.004* (25.48)

Note: Values are unstandardized B coefficients indicating monthly change
. % Product dollars from promotion means the percentage of product category dollars sold at a promoted (discount) price. % Product dollars from largest size means the percentage of product category dollars coming from the largest package size(s). Largest package sizes are for flower 7G, 14G and 28G; for vapor pen 1G; for concentrate 1G and 2G; for pre-roll 2G, 2.4G, 2.5G, 3G, 3.5G, 5G and 7G; for edible/beverage 100 mg THC, 150 mg THC, 250 mg THC and 1000 mg THC; and for absorbable 101–250 mg THC, 251–450 mg THC, 451–1000 mg THC and 1001+ mg THC. Price/gram pertains to flower, vapor pen, concentrate and pre-roll while, price/THC pertains to edible/beverage and absorbable (tincture/sublingual, capsule and topical).
Abbreviation: THC, tetrahydrocannabinol.
*$P < 0.001$ with t-statistics in parentheses.

from promotion, growth is substantial but comparable across products.

DISCUSSION

Based on recreational cannabis retail purchases by age in California from 2018 to 2021, the product categories of flower, vapor pen and concentrate have more young-adult appeal than pre-roll, edible/beverage and absorbable products (tincture/sublingual, capsule and topical). Young and older adults purchase more flower than any other product. However, relative to older adults, young adults spend a greater share of their cannabis dollars on vapor pen and concentrate. Based on monthly sales trend coefficients, flower and vapor pen dollar sales are growing faster than other cannabis products. Furthermore, vapor pen has undergone the steepest price decline, and is tied for fastest growth in the percentage of dollar sales from the largest package size.

Young adults buy considerable flower, which they may use in bongs and joints [23]. They may find flower appealing because of its familiarity, versatility, shareability, lower cost and/or rapid and relatively predictable psychoactive effects [23, 25]. However, flower's dollar share ratio among young adults is 84 (100 = age comparable), meaning that young adults devote a somewhat lower share of their cannabis purchases to flower than older adults and, in turn, they devote more of their purchases to concentrate and vapor pen, both of which have dollar share ratios of 152. One reason for the appeal of extracts such as concentrate and vapor pen is their high THC potency, approximately three times that of flower (69 versus 21%) [5, 14], which may attract young adults [26]. Vapor pen has the additional benefits of convenience, portability and minimal odor [27, 28]. Moreover, a cannabis vapor pen is similar to a nicotine vapor device, thus familiar to young adults, many of whom perceive vaping as a safer delivery mechanism for both cannabis and nicotine [29].

On virtually all indicators, pre-roll, edible/beverage and absorbable products are not as appealing to young adults as other offerings, although some specific pre-rolls and edible gummies have slightly elevated sales or share ratios. The psychoactive effects of edible and beverage tend to be delayed, unpredictable or excessive, which may reduce their appeal among young adults [25, 30]. Edible products are also substantially more expensive in terms of price/10 mg THC, estimated at $3 for edible versus 70 cents for vapor pen and 30–40 cents for flower [14]. The products we call absorbable (tincture/sublingual, capsule and topical products) are often used for health purposes, and young adults face fewer health issues [31, 32].

Strengths and limitations

This study is the first, to our knowledge, to examine recreational cannabis retail sales and trends by age in the first 4 years of legalization in the nation's largest market, which is California. Retail data provides useful, novel and nuanced insights into cannabis use because it captures regular buying patterns, including by age. It allows the identification of products with high sales due to frequent and/or heavy use, compared to products with lower sales due to occasional and/or lighter use.

Nevertheless, significant limitations apply to our work. The proprietary Headset data set we used was collected from approximately one quarter of California retailers and may not be optimally representative, although other databases widely used in marketing research, for example Nielsen panels, capture even smaller proportions of the market. Some purchase data may be partially or fully missing, and sampling and data imputation are not fully transparent, which are familiar challenges with commercial data sets. Our data set excludes medicinal cannabis sales. Our study pertains only to California and generalizability to other markets is unknown.

Using cannabis retail purchase data also has inherent limitations. Commercial data sets are costly and state-run track-and-trace systems are not always widely available to researchers. Retail data are typically unavailable wherever sales are illegal. Commercial data sets tend not to include unlicensed retailers, underage buyers and illegal products. Buyers may be purchasing for others, not for themselves. Buyer demographics are generally limited. Retail sales data do not provide population-based use prevalences (i.e. users as a percentage of the population), as only those who buy from legal retail outlets are sampled. Buyer age is generally recorded in the buyer profile for retailer loyalty programs, but loyalty programs could possibly be skewed towards certain age groups. Nevertheless, cannabis retail data holds considerable promise for understanding cannabis market trends to aid researchers in public health, addiction, marketing and public policy [15].

PUBLIC HEALTH IMPLICATIONS

Monitoring consumption of cannabis products by age is important because young adults are more vulnerable than older adults to cannabis use disorders and psychosis, both of which are associated with high THC potency [7, 10, 12]. Thus, regulators and public health officials should monitor cannabis sales by both buyer age and product category. They should use metrics such as those presented here to identify the young-adult appealing product categories, which in California are currently vapor pen, concentrate and flower, although this could change or differ in other locations. As vapor pen and concentrate are young-adult appealing and have high and rising THC potency [14], policies which may dampen young-adult consumption of these products should be considered; for example, THC-potency surtaxes. A potency surtax is already used in Illinois and should differentially affect young adults who regularly use cannabis, due to their increased price sensitivity relative to older adults [33]. Declining cannabis prices, especially for vapor pen, indicates price promotion restrictions should be contemplated. Price promotions have long been banned for cigarettes in many countries [34]. Vapor pen's package size growth suggests that policymakers should also consider package size (quantity) limits, already utilized for cannabis edibles [35]. The time to act is now, while the market-place is still relatively immature and malleable.

AUTHOR CONTRIBUTIONS

Cornelia 'Connie' Pechmann: Conceptualization (lead); data curation (lead); formal analysis (lead); funding acquisition (equal); investigation (lead); methodology (lead); project administration (lead); supervision (lead); writing—original draft (lead); writing—review and editing (lead). **Douglas Calder:** Data curation (equal); formal analysis (equal). **David Timberlake:** Funding acquisition (equal); project administration (equal); writing—original draft (equal); writing—review and editing (equal). **Joshua Rhee:** Writing—original draft (equal); writing—review and editing (equal). **Alisa Padon:** Writing—original draft (equal); writing—review and editing (equal). **Lynn Silver:** Funding acquisition (lead); writing—original draft (equal); writing—review and editing (equal).

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DECLARATION OF INTERESTS

None to declare.

DATA AVAILABILITY STATEMENT

We purchased the cannabis retail sales dataset from a marketing research company called Headset and, while we cannot share the dataset, other researchers should be able to purchase comparable data from Headset.

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SUPPORTING INFORMATION

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

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