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Demographic Changes in the Prevalence of Marijuana use in the United States, 2005 to 2016

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Title

Demographic Changes in the Prevalence of Marijuana use in the United States, 2005 to 2016.

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Marijuana, marijuana use, drug use, illicit, legalization

Abstract

Importance: Understanding trends of marijuana use in the United States (US) throughout a period of particularly high adoption of marijuana legalization, and understanding which demographics are most at risk of use, is important in managing evolving healthcare policy and intervention.

Objective: To study the demographic-specific changes in the prevalence of marijuana use in the US between 2005-2016.

Design, Setting and Participants: Analysis of National Health and Nutrition Examination Survey weighted US survey data. A total of 30,402 adults between 18-69 years old participated between January 2005-December 2016.

Primary Outcome Measured: Lifetime use, recent use and use in adolescence of marijuana.

Results: The majority of US adults reported ever using marijuana. While the overall prevalence of lifetime marijuana use remained stable ($p=0.17$), recent use increased significantly between 2005 and 2016 ($p=0.01$) with highest rate of recent use among younger age groups ($p<0.001$), males ($p<0.001$), and those with income below poverty level ($p<0.001$). Recent marijuana use was most common among non-Hispanic blacks, and less common among Hispanic/Mexican populations ($p<0.05$). Trends in recent use increased among older adults ($p<0.001$), females ($p=0.003$), and those with high school education or above ($p=0.04$).

Conclusions: While lifetime marijuana use remained stable, recent use significantly increased over the 12-year period. While recent use was remained commonest in younger age groups, males, non-Hispanic blacks and those with lower income; increasing trends in recent use were significant for older, female, and highly-educated populations. With high legalization adoption during this period, our results may suggest an associated increase in recent marijuana use.

An accurate understanding of those most at risk can help inform decisions of healthcare policy makers and healthcare professionals, and facilitate a safe transition of changing marijuana legalization and use in the US.

Article Summary

- This is the most recent study of trends of marijuana use in the United States, during a period of particularly high rates of adoption of marijuana legalization laws.
- The National Health and Nutrition Examination Survey (NHANES) database is a publicly-available and nation-wide database. The NHANES database is weighted (standardized), to accurately represent the entire population of the United States.
- The NHANES database is self-reported, and limited by reporter bias.
- Missing data was primarily from participants who were older and female, potentially underestimating the true prevalence of marijuana use among this demographic.
- State-based legalization information was not available, and could not be accurately correlated to changing trends of marijuana use.

Manuscript

Introduction:

While remaining illegal at the federal level in the United States (US), marijuana is now legal for recreational use by adults over the age of 21 in 11 states, and for medical use in 33 states (1, 2). With particularly high adoption rates of medical marijuana legalization between 2007 and 2016 (3), and increasing social acceptability of marijuana use (4-6), describing trends in use among different demographics in the US is important in understanding which populations might be most affected by changing laws.

Prior studies have described increases in both marijuana use and misuse trends since medical marijuana legalisation (4, 7, 8) in marijuana users both domestically and overseas (9, 10). However, some studies have shown no changes to trends of recent use since legalisation (11, 12), and others have shown only increases in marijuana misuse (12). A recent analysis even described a significant decrease in marijuana misuse disorder since legalisation (13). There have also been inconsistent reports of the demographics of those most affected by changing medical and recreational marijuana legalisation; some studies describing increasing trends across all gender, age and ethnic demographics (7), some showing trend changes particularly for young, black, and Hispanic men (12), and others showing changes particularly among older individuals (4, 6, 14). Importantly, changing trends in medical and non-medical marijuana use do not appear to be restricted only to states with changing marijuana laws (15), despite being higher in states where laws have been passed (7). An understanding of both the social and the economic cost-effectiveness of legalising marijuana (16, 17), coupled with an understanding of trends of changing use, may be useful for those working in public health, public policy, and healthcare, responsible for policy intervention or caring for populations most affected by marijuana use.

The current paper uses data from the US National Health and Nutrition Examination Survey (NHANES), a nationally-representative sample of US adults, to examine the most recent 12-year trends in marijuana use in the United States. Additionally, we examine sociodemographic factors associated with marijuana use. We explore recent literature regarding the cost-effectiveness of medical and social marijuana legalization, adding to the current body of literature important for those in policy, or caring for those most affected.

Methods:

The National Health and Nutrition Examination Survey (NHANES) is an on-going biennial cross-sectional survey representing a non-institutionalized civilian US population, performed by the National Centre for Health Statistics and Centres for Disease Control and Prevention.

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3 Participants undergo a home interview and a comprehensive physical examination in
4 a mobile examination centre (MEC). The 2005-2016 NHANES protocol was approved by the
5 National Centre for Health Statistics research ethics review board and written informed
6 consent obtained from all participants.
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10 Demographics data including age, gender, race/ethnicity, education and income were
11 collected during the home interview. The drug use questionnaire was conducted in the MEC
12 and aimed to assess lifetime and current usage of illicit drugs. Questions are self-administered
13 using the Audio Computer-Assisted Self-Interview (ACASI) system. The ACASI was conducted
14 in English, Spanish, Korean, Vietnamese, or Chinese (Mandarin and Cantonese). Participants
15 reported lifetime use, age at first use and use within prior 12 months of marijuana. We
16 defined *recent use* as any survey responses stating use within the previous 12 months.
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21 All analyses were restricted to adults aged 18 to 69 years. Given the NHANES complex
22 probability sampling design, 2-year interview weights computed by the National Center for
23 Health Statistics were used to calculate prevalence estimates and 95% confidence interval.
24 Differences in prevalence estimates were compared using chi-square tests. Univariate
25 regression models were used to test for significant linear trends while multivariable
26 regression models were used to determine characteristics associated with recent marijuana
27 use. Statistical analysis was performed using STATA (version 15).
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32 Patients or the public were not involved in the design, or conduct, or reporting, or
33 dissemination plans of our research.
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38 **Results:**

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40 A total of 30,402 adults between 18-69 years old participated in NHANES 2005-2016 surveys.
41 Of these 9,987 (27.13%) had missing survey data. Those with missing data were significantly
42 more likely to be older ($p<0.001$), female ($p<0.001$) and have less than high school education
43 ($p<0.001$).
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48 Overall, 59.2% (CI 57.7% - 60.7%) of the US adult population reported ever using marijuana
49 between 2005-2016. The prevalence of lifetime marijuana use remained stable between 2005
50 and 2016 ($p=0.17$) (Table 1). Overall 18.8% (CI 15.2-23.5) of US adults reported using
51 marijuana within the last year. The weighted prevalence of recent marijuana use increased
52 significantly during the study period from 19.1% (95% CI 15.3-23.7%) in 2005/06 to 24.9%
53 (95%CI 20.0-30.5) ($p=0.02$) in 2015/16.
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58 The prevalence of recent marijuana use was higher among younger age groups ($p<0.001$),
59 males ($p<0.001$), and those with income below poverty level ($p<0.001$) (Table 2). Recent
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3 marijuana use was more common among non-Hispanic blacks, and less common among
4 Hispanic/Mexicans ($p < 0.002$ (excluding 2011-2012)). Between 2005 - 2016 the prevalence of
5 recent marijuana use increased among older adults (age 50-69, $p < 0.001$), females ($p = 0.003$),
6 all racial categories ($p < 0.05$ for all groups), and those with high school education or above
7 ($p = 0.04$ for both)
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11 Multivariate logistic regression analysis demonstrated higher odds of recent marijuana use
12 among males ($p < 0.001$), non-Hispanic blacks ($p = 0.008$) and those with income within 2x or
13 below the poverty level ($p < 0.001$ for both) (Table 3). Recent use was less likely among older
14 individuals ($p < 0.001$), Hispanic and Mexican Americans ($p < 0.001$) and those with more than
15 high school education ($p < 0.001$) (Table 3).
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22 **Discussion:**

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24 While lifetime marijuana use remained stable, overall prevalence of recent use within the
25 previous 12-months significantly increased over the 12-year period. While recent use was
26 more common in younger age groups, males, non-Hispanic blacks and those with lower
27 income, significant trends of increasing recent use were most notable for older, female, and
28 highly-educated populations.
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33 Our demographic findings of those most likely to have used marijuana are consistent with
34 previous studies, demonstrating highest overall use among younger, males, non-Hispanic
35 blacks, and lower income groups (4, 7). Native American populations, those living in urban
36 areas, and those living in western states, have also been shown to be more likely to have
37 recently used marijuana; but these demographic factors were not included in our analyses.
38 The characteristics of those most likely to have used medical-marijuana have been shown to
39 be altogether different; tending to be in slightly older age groups (30-50 years old), males,
40 white, and with higher annual incomes (15).
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46 Particularly high uptake of medical and recreational marijuana legalization in the US between
47 2007-2016 (3), with paralleled increasing marijuana-use trends particularly during this period
48 (4), may suggest an association between marijuana legalization and use. However, specific
49 demographics most affected by changing laws, whether recreational or medical users are
50 more affected, and changes in marijuana misuse trends, remain inconsistently described (12).
51 Where previous studies have concluded comparably increased use across ages and gender (4,
52 6, 7, 12), changing trends in adolescents remains unclear. While younger people have
53 appeared likelier to use recreational marijuana after legalization in some instances (8), Harpin
54 and colleagues describe no significant change to use among college students after legalization
55 (despite changes to perceived ease of access) (11), supported by more recent reviews
56 describing stable adolescent trends (6). In fact, a recent study describes that recent marijuana
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3 misuse appears to have *decreased* among US adolescents during the highest periods of
4 legalization uptake (13). More recent reviews outline that marijuana legalization results in
5 significantly increased use in older populations only, without affecting adolescents (6, 14);
6 corroborated by recent findings by Salas-Wright and colleagues demonstrating increasing
7 trends of recent use among late middle-aged adults between 2002-2014 (5). The extent to
8 which different demographics remain most at risk of medical or recreational use or misuse
9 remains unclear.
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14 Importantly, increasing trends of marijuana use appears not to be restricted to states with
15 changing legalization laws. Hasin and colleagues demonstrate significantly increased use seen
16 both in states with and without marijuana legalization (4, 7), albeit fractionally higher in states
17 where marijuana was legalized. However, a recent analysis by Han and colleagues
18 demonstrated a significantly higher trend of increasing medical marijuana use in states
19 without legalization (AOR 1.4, 95% CI 1.05-1.90), compared to states with legalization (AOR
20 1.3, 95% CI 1.03-1.61) (15). This underlines the fact that evolving legalization laws are also of
21 relevance to states where recreational and medical marijuana use remains illegal.
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27 In addition to demographic risk factors indicating potential marijuana use, an understanding
28 of other risk factors is important for those involved in fields of public policy and healthcare.
29 While age and gender remain somewhat inconsistently described risk factors, tobacco
30 smoking has been demonstrated a significant risk factor for marijuana use. A recent study
31 demonstrated that current smokers have almost 6x increased odds of recent marijuana use
32 compared to non-smokers (18), outlining another sub-population particularly at risk. Another
33 group at risk of increasing marijuana use are non-medical users of prescription drugs
34 (NMUPD). A recent study by Karjalainen and colleagues demonstrated significantly increasing
35 trends of illicit drug use among NMUPD (92% of whom had used cannabis in the last year),
36 that could not otherwise be explained by age or gender (19).
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43 Exploring the economic and societal cost-effectiveness of marijuana legalization is important
44 for those involved in healthcare policy and decision making. Marijuana legalization was
45 posited to lower price, increase availability, and thereby increase marijuana use (6), with early
46 fears that profit motive would take precedence over public health issues (20, 21). The retail
47 price of marijuana on the legal cannabis market had sharply fallen by almost 70%, just three-
48 years after legalization in Washington State (22, 23). Some reports described an initial
49 increase in self-reported street prices of marijuana in response to legalization as demand
50 increased, by up to 36% (24), with limited price change thereafter. However, similarly to
51 results aforementioned, medical legalization appears to have affected only adult marijuana
52 use, with minimal significant changes to adolescent use (14). While studies of the effect of
53 recreational marijuana legalization on its use are still emerging, there appears to be
54 no/minimal effect on adolescent or college marijuana use (14). The passage of legalization
55 laws also offers an important social justice benefit (25); by removing mechanisms for unfair,
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damaging disparities in law enforcement (26). While more permissive marijuana laws may appeal to social justice aims (reducing racial disparity in law enforcement), and increase revenue to state and local government through taxation (6), the public health trade-offs and overall costs of use-related adverse physical and psychosocial consequences (27) in response to changing laws remains difficult to accurately describe (6).

Strengths and Limitations: Limitations to our study include reliance on self-reported data and reporter-bias. Missing data was primarily from participants who were older and female, potentially underestimating the true prevalence of marijuana use among this demographic. Our dataset excluded youth aged 12-17 years old, a potentially at-risk population. Strengths of our study include the size and heterogeneity of our population, the timespan, and the standardization of the NHANES data.

Conclusion:

Our primary two findings describing characteristics of those most at risk of using marijuana, and those where trends of use have most significantly increased, adds to the current body of literature and understanding of marijuana trends in the United States. Given ongoing changes to legalization in the US, with the evolving public perception of marijuana safety and accessibility, an accurate understanding of which populations are most likely to be implicated, which additional predictive tools can identify those most at risk, and a balanced presentation of healthcare, social and economic costs of legalization, is warranted. Identification of these factors can help inform the decisions of healthcare policy makers and professionals, and facilitate a safe transition of changing marijuana legalization and use in the US.

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Author contributions:

Dr William Mitchell: Analysis plan, data interpretation, manuscript generation and editing, submission, correspondence

Dr Roma Bhatia: Analysis plan, data interpretation, manuscript editing

Dr Nazlee Zebardast: Analysis plan, data extraction, analysis and interpretation, manuscript editing

Data Statement:

Data is fully accessible from the following website:

<https://wwwn.cdc.gov/nchs/nhanes/default.aspx>

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Table 1: Prevalence of marijuana and cocaine/heroin/methamphetamine use in US adults, NHANES 2005-2016

	2005-2006		2007-2008		2009-2010		2011-2012		2013-2014		2015-2016		P
	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	
Lifetime use	2922	61.5 (57.2-65.7)	3255	60.5 (57.2-63.7)	3739	57.2 (53.0-61.3)	3333	59.9 (56.0-63.6)	3690	59.2 (55.6-62.7)	3422	57.3 (53.1-61.5)	0.17
Age at First used (<18 years old)	1617	59.6 (56-7-62.7)	1799	60.7 (58.0-63.5)	1937	62.7 (59.0-66.4)	1770	60.1 (56.0-64.0)	1984	61.4 (58.8-63.9)	1715	60.1 (56.5-63.7)	0.91
Recent use (≤ 12 months)	2922	19.1 (15.3-23.7)	3255	19.1 (17.5-20.7)	3739	20.6 (18.2-23.3)	3333	22.4 (19.8 - 25.2)	3690	22.3 (19.9-24.8)	3422	24.9 (20.0-30.6)	0.02

Key:
 N denotes unweighted total number of participants in each category
 Prevalence percentage with 95% (CI), computed using 2-year MEC weights to provide estimates for the total US population, and age-standardized to 2000 Census population.
 P values test overall trend in prevalence estimates in each category
 NHANES = National Health and Nutrition Examination Survey

Table 2: Prevalence of self-reported recent marijuana use by demographic factors, NHANES 2005-2016.

	2005-2006	2007-2008	2009-2010	2011-2012	2013-2014	2015-2016	P value
	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	
Age of participants							
- 18-29	34.0 ^a (26.7-42.0)	35.1 (30.0-40.6)	34.4 (30.7-38.3)	36.2 (31.7-41.1)	38.1 (35.1-41.2)	37.3 (30.4-44.8)	P=0.28 ^c
- 30-49	16.1 (12.3-20.7)	16.2 (14.3-18.2)	17.5 (14.7-20.7)	17.0 (14.4-20.1)	16.3 (13.8-19.1)	21.1 (16.0-27.3)	P=0.15
- 50-69	10.5 (7.4-14.6) P<0.001 ^b	8.1 (6.0-10.9) P<0.001	10.3 (7.8-13.4) P<0.001	15.5 (11.4-20.8) P<0.001	14.3 (9.2-21.5) P<0.001	18.0 (13.0-23.7) P<0.001	P<0.001
Gender							
- Male	24.8 (20.3-29.9)	23.1 (20.8-25.7)	24.8 (22.0-27.8)	27.3 (24.6-30.1)	26.3 (23.2-29.7)	29.2 (23.1-36.3)	P=0.09
- Female	13.6 (10.1-18.1) P<0.001	15.1 (13.1-17.3) P<0.001	16.3 (13.6-19.3) P<0.001	17.3 (14.0-21.2) P<0.001	18.2 (15.3-21.6) P=0.001	20.6 (16.5-25.4) P<0.001	P=0.003
Race							
- Non-Hispanic White	20.1 (15.6-25.7)	19.4 (17.7-21.3)	21.1 (18.4-24.1)	22.7 (19.4-26.3)	22.0 (18.3-26.3)	26.7 (20.4-34.1)	P=0.049
- Non-Hispanic Black	23.56 (18.4-29.1)	26.9 (22.6-31.7)	27.6 (24.6-30.9)	27.3 (22.1-33.2)	32.9 (29.8-36.1)	32.5 (28.8-36.5)	P=0.001
- Hispanic/Mexican	11.7 (8.3-16.2)	13.6 (9.8-18.5)	16.6 (13.0-20.9)	18.9 (15.2-23.2)	17.9 (15.5-20.6)	16.3 (13.1-20.2)	P=0.03
- Other	13.2(7.9-21.2) P=0.003	13.3 (7.5-22.6) P=0.002	12.7 (7.4-21.1) P<0.001	18.7 (14.2-24.1) P=0.06	18.0 (13.7-23.3) P<0.001	19.9 (13.3-28.7) P=0.001	P=0.06
Educat.							
- <High School	22.5 (16.5-30.0)	22.1 (17.6-27.3)	23.3 (19.5-27.6)	27.5 (22.6-33.0)	27.9 (23.6-32.6)	24.7 (20.0-30.1)	P=0.13
- High School	21.6 (15.1-30.0)	19.6 (17.5-21.8)	24.7 (21.2-28.5)	25.8 (20.8-31.5)	25.4 (21.1-30.3)	27.5 (22.3-33.4)	P=0.04
- >High School	17.4 (13.2-22.7) P=0.25	18.0 (15.4-20.8) P=0.21	18.2 (15.1-21.9) P=0.006	20.2 (17.2-23.4) P=0.01	19.8 (16.9-23.0) P=0.01	24.1 (18.2-31.3) P=0.42	P=0.04
Poverty							
- >2x Poverty Level	17.7 (13.5-22.8)	16.3 (14.4-18.5)	17.1 (14.2-20.5)	18.3 (15.6-21.3)	18.5 (15.7-21.6)	22.4 (17.3-28.4)	P=0.09
- 1-2X Poverty Level	22.0 (16.4-28.8)	24.5 (20.8-28.6)	22.4 (18.0-27.7)	27.9 (23.8-32.3)	25.3 (21.6-29.5)	29.4 (21.8-38.4)	P=0.08
- < Poverty Level	24.3 (19.2-30.2) P=0.05	25.2 (19.5-32.0) P=0.001	34.6 (30.9-38.6) P<0.001	31.1 (27.1-35.4) P<0.001	33.2 (28.3-38.6) P<0.001	29.8 (23.6-37.0) P=0.004	P=0.07

Key:

Prevalence percentage with 95% confidence intervals (CI), computed using 2-year interview weights to provide estimates for the total US population and are age-standardized to the US 2000 Census population.

^a percentage interpretation: of those aged 18-29, 34% reported marijuana use within the past 12 months. Poverty defined using poverty income ratio, accounting for family size

^b P values test global within group differences in prevalence

^c P values test overall trend in prevalence estimates in each category

NHANES = National Health and Nutrition Examination Survey

Table 3: Multivariable logistic regression analysis predicting recent marijuana use within the past 12 months NHANES 2005-2016

Demographic variable	Recent marijuana use (past 12 months) OR (95% CI)
Age of participants	
- 18-29	1.0 (reference)
- 30-49	0.39 (0.35-0.43)
- 50-69	0.27 (0.23-0.31)
Gender	
- Female	1.0 (reference)
- Male	1.77 (1.62-1.92)
Race	
- Non-Hispanic White	1.0 (reference)
- Non-Hispanic Black	1.20 (1.05-1.38)
- Hispanic/Mexican	0.47 (0.41-0.55)
- Other	0.63 (0.53-0.75)
Education	
- < High School	1.0 (reference)
- High School	0.93 (0.79-1.10)
- > High School	0.81 (0.70-0.92)
Poverty	
- >2x Poverty Level	1.0 (reference)
- 1-2X Poverty Level	1.41 (1.24-1.59)
- < Poverty Level	1.69 (1.49-1.92)

Key:

Odds ratio (OR) with 95% confidence intervals (CI) computed using 12-year interview weights to provide estimates for the total US population and are age-standardized to the US 2000 Census population.

Poverty defined using poverty income ratio, which accounts for family size

NHANES = National Health and Nutrition Examination Survey

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3 1 **Title**
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7 3 **A Retrospective Cross-Sectional Analysis of the Changes in Marijuana Use in the United States, 2005-**
8 **2018**
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Abstract

Objectives: Understanding trends of marijuana use in the United States (US) throughout a period of particularly high adoption of marijuana-legalization, and understanding demographics most at risk of use, is important in evolving healthcare-policy and intervention. This study analyzes the demographic-specific changes in the prevalence of marijuana use in the US between 2005-2018.

Design, Setting and Participants: A fourteen-year retrospective cross-sectional analysis of the National Health and Nutrition Examination Survey (NHANES) database, a publicly-available biennially-collected national survey, weighted to represent the entire US population. A total of 35,212 adults between 18-69 years old participated in the seven-cycles of surveys analysed (2005-2018).

Primary Outcome Measured: Lifetime-use, first-use before 18-years-old, and past-year use of marijuana.

Results: The majority of adults reported ever using marijuana. While the overall prevalence of lifetime marijuana use remained stable ($p=0.53$), past-year use increased significantly between 2005-2018 ($p<0.001$) with highest rate of past-year use among younger age groups ($p<0.001$), males ($p<0.001$), and those with income below poverty level ($p<0.001$). Past-year use was commonest among non-Hispanic blacks, and less common among Hispanic/Mexican populations ($p<0.002$). Trends in past-year use increased among all age categories, males/females, all ethnicities, those with high-school education/above, and those at all income levels ($p<0.01$ for all).

Conclusions: While lifetime marijuana-use remained stable, past-year use significantly increased between 2005-2018. While past-year use remained commonest in younger age groups, males, non-Hispanic blacks and those with lower income; increasing trends in past-year use were significant for all age, sex, race and income categories, and for those with high-school education/above. With high adoption of marijuana-legalization laws during this period, our results suggest an associated increase in past-year marijuana use.

An accurate understanding of those most at risk can help inform decisions of healthcare policy makers and professionals, and facilitate a safe transition of changing marijuana legalization and use in the US.

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3 69 **Article Summary**
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- 6 71 - This is the most recent study of trends of marijuana use in the United States, during a
7 72 period of particularly high rates of adoption of marijuana legalization laws.
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9 73 - The National Health and Nutrition Examination Survey (NHANES) database is a
10 74 publicly-available and nation-wide database. The NHANES database is weighted
11 75 (standardized), to accurately represent the entire population of the United States.
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13 76 - The NHANES database is self-reported, and limited by reporter bias.
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15 77 - Missing data was primarily from participants who were older and female, potentially
16 78 underestimating the true prevalence of marijuana use among this demographic.
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18 79 - State-based legalization information and use amongst adolescents less than 18-years-
19 80 old was not available, and could not be accurately correlated with changing trends of
20 81 marijuana use.
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Manuscript

Introduction:

While remaining illegal at the federal level in the United States (US), marijuana is now legal for recreational use by adults over the age of 21 in 11 states, and for medical use in 33 states (1, 2). With particularly high adoption rates of medical marijuana legalization between 2007 and 2016 (3), and increasing social acceptability of marijuana use (4-6), describing trends in use among different demographics in the US is important in understanding which populations might be most affected by changing laws.

Prior studies have described increases in both marijuana use and misuse trends since medical marijuana legalisation (4, 7, 8) in marijuana users both domestically and overseas (9). However, some studies have shown no changes to trends of past-year use since legalisation (10, 11), and others have shown only increases in marijuana misuse (11). A recent analysis even described a significant decrease in marijuana misuse disorder since legalisation (12). There have also been inconsistent reports of the demographics of those most affected by changing medical and recreational marijuana legalisation; some studies describing increasing trends across all gender, age and ethnic demographics (7), some showing trend changes particularly for young, black, and Hispanic men (11), and others showing changes particularly among older individuals (4, 6, 13). Importantly, changing trends in medical and non-medical marijuana use do not appear to be restricted only to states with changing marijuana laws (14), despite being higher in states where laws have been passed (7). An understanding of both the social and the economic cost-effectiveness of legalising marijuana (15, 16), coupled with an understanding of trends of changing use, may be useful for those working in public health, public policy, and healthcare, responsible for policy intervention or caring for populations most affected by marijuana use.

The current paper uses data from the US National Health and Nutrition Examination Survey (NHANES), a nationally-representative sample of US adults, to examine the most recent 12-year trends in marijuana use in the United States. Additionally, we examine sociodemographic factors associated with marijuana use. We explore recent literature regarding the cost-effectiveness of medical and social marijuana legalization, adding to the current body of literature important for those in policy, or caring for those most affected.

Methods:

The National Health and Nutrition Examination Survey (NHANES) is an on-going biennial cross-sectional survey representing a non-institutionalized civilian US population, performed by the National Centre for Health Statistics (NCHS) and Centres for Disease Control and

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3 124 Prevention (CDC). NHANES has been a continuous survey program providing health statistics
4 125 for the US since 1999, examining a nationally-representative sample of about 5,000 people
5 126 each year, located in counties across the US. Study teams consisting of multilingual physicians,
6 127 medical and health technicians, and dietary health interviewers conduct interviews and
7 128 perform examinations, and information collected is intended to be used to determine the
8 129 prevalence of major diseases and risk factors for diseases, and for health promotion and
9 130 disease prevention. The sample for the survey is selected to represent the US population of
10 131 all ages. To produce reliable statistics, NHANES over-samples persons 60 and older, African
11 132 Americans, and Hispanics (17).
12 133

13 134 In the present study, seven two-year cycles of NHANES survey data between 2005-2018
14 135 (inclusive) have been retrospectively analysed for baseline demographic information, and
15 136 drug use questionnaire data. A total of 35,212 adults (US citizens) between 18-69 years old
16 137 participated in the seven-cycles of surveys analysed. Of these, 32.9% had missing marijuana
17 138 survey data. Those with missing data were significantly more likely to be older ($p<0.001$),
18 139 female ($p<0.001$) and have less than high school education ($p<0.001$). Missing data was
19 140 handled by pairwise deletion to optimize data available for analysis. Participants undergo a
20 141 home interview, and a comprehensive physical examination in a mobile examination centre
21 142 (MEC). The 2005-2018 NHANES protocol was approved by the National Centre for Health
22 143 Statistics research ethics review board and written informed consent obtained from all
23 144 participants.
24 145

25 146 Demographics data including age, gender, race/ethnicity, education and income were
26 147 collected during the home interview. The drug use questionnaire was conducted in the mobile
27 148 examination centre (MEC), and aimed to assess lifetime, past-year, and current usage of
28 149 marijuana. Questions are self-administered using the Audio Computer-Assisted Self-Interview
29 150 (ACASI) system. The ACASI was conducted in English, Spanish, Korean, Vietnamese, or Chinese
30 151 (Mandarin and Cantonese). Participants reported lifetime use, age at first use and use within
31 152 the past-year of marijuana.
32 153

33 154 Given the NHANES complex probability sampling design, 2-year interview weights computed
34 155 by the NCHS were used to calculate prevalence estimates and 95% confidence intervals
35 156 (Taylor linearization), age-standardized to the 2000 US Census population as recommended
36 157 by the NCHS. Differences in prevalence estimates were compared using chi-square tests.
37 158 Univariate regression models were used to test for significant linear trends while
38 159 multivariable regression models were used to determine characteristics associated with
39 160 recent marijuana use. Results at the $p<0.05$ level considered statistically significant. Statistical
40 161 analysis was performed using STATA version 15.0 (StataCorp LP, College Station, TX).
41 162

42 163 Patients or the public were not involved in the design, or conduct, or reporting, or
43 164 dissemination plans of our research.

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Results:

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168 Overall, 53.5% (95% CI 52.8-54.1%) of the US adult population reported ever using marijuana
169 between 2005-2018. The prevalence of lifetime marijuana use, and first use before the age
170 of 18, remained stable between 2005 and 2018 ($p=0.53$ and $p=0.68$, respectively) (Table 1).
171 Overall 22.6% (95% CI 22.1-23.1%) of US adults reported using marijuana within the last year.
172 The weighted prevalence of past-year marijuana use increased significantly during the study
173 period from 19.1% (95% CI 15.3-23.7%) in 2005/06 to 29.1% (95% CI 26.0-32.5%) ($p=0.001$) in
174 2017/18.

175

176 The prevalence of past-year marijuana use was higher among younger age groups ($p<0.001$),
177 males ($p<0.05$), and those with income below poverty level ($p<0.05$) (Table 2). Past-year
178 marijuana use was more common among non-Hispanic blacks, and less common among
179 Hispanic/Mexicans ($p<0.002$ (excluding 2011/12 and 2017/18)). Between 2005 - 2018 the
180 prevalence of past-year marijuana use increased among all age categories ($p<0.001$), males
181 and females ($p<0.001$), all racial categories ($p<0.01$ for all groups), those with high school
182 education or above ($p<0.001$ for both) and those at all levels of income ($p<0.01$).

183

184 Multivariate logistic regression analysis demonstrated higher odds of past-year marijuana use
185 among younger age groups ($p<0.001$), males ($p<0.001$), non-Hispanic blacks ($p<0.001$), and
186 those with income below the poverty level ($p<0.001$ for both) (Table 3). Past-year use was
187 less likely among older individuals ($p<0.001$), and Hispanic and Mexican Americans ($p<0.001$)
188 and those with higher levels of education ($p=0.003$) (Table 3).

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Discussion:

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193 The current study presents the most recent changes in marijuana use in the US during a period
194 of particularly high legalization. It finds that while lifetime marijuana use, and first-use before
195 the age of 18, has remained stable, the overall prevalence of past-year marijuana use has
196 significantly increased over the 14-year period. While past-year use was still more common
197 among younger age groups, males, non-Hispanic blacks and those with lower income,
198 significant trends of increasing past-year use were seen in all age categories, males and
199 females, all racial categories, highly-educated populations, and all income levels. Age-specific
200 marijuana use trends in response to legalization laws has been studied elsewhere; but with
201 inconsistent findings. There has been growing consensus that increasing recent-use of
202 marijuana is seen among late to middle-aged adults after legalization (6, 13); a recent study
203 by Salas-Wright and colleagues showing trends of increasing past-year use among late to
204 middle-aged adults in the US between 2002-2014 (5), findings that are supported by the
205 present study. Whether this pattern of recent-use among older populations is associated with

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3 206 increasing marijuana-use for medicinal purposes (seen most prominently among older, white,
4 207 male, and high-income populations in the US) (14), is unclear, and such data was not available
5 208 for analysis in the present study. However, there has been less consensus about recent-use
6 209 trends among adolescent populations. While a comprehensive study by Harpin and
7 210 colleagues described no change in adolescent-use after legalization (10) (further supported
8 211 by more recent findings (6)), a 2019 review by Bae and colleagues described increasing recent-
9 212 use amongst adolescents in the US after legalization (8). Contrastingly, a 2016 US study by
10 213 Grucza and colleagues describes that past-year marijuana use actually *decreased* among
11 214 adolescents, during the highest periods of legalization (12). Information about marijuana-use
12 215 trends in adolescents less than 18-years-old was not publicly available on NHANES for the
13 216 present study, but it has been noted that over the 14-year study period, there has been no
14 217 significant change in reported first-use before the age of 18 (table 1).
15 218

16 219 Our findings of younger, male, non-Hispanic black and lower income populations being most
17 220 likely to use marijuana overall, are also consistent with previous findings not aforementioned
18 221 (4, 7). Native American populations, those living in urban areas, and those living in western
19 222 states, have also been shown to be more likely to have recently used marijuana; but this
20 223 information was not available on NHANES in sufficient detail, for the present analyses.
21 224

22 225 In addition to demographic risk factors indicating potential marijuana use, an understanding
23 226 of other risk factors is important for those involved in fields of public policy and healthcare.
24 227 While age and gender remain somewhat inconsistently described risk factors, tobacco
25 228 smoking is a demonstrated risk factor for marijuana use. Though not analyzed in the present
26 229 study, a recent study demonstrated that current smokers have almost 6x increased odds of
27 230 recent marijuana use compared to non-smokers (18), outlining another sub-population
28 231 particularly at risk. Another group at risk of increasing marijuana use are non-medical users
29 232 of prescription drugs (NMUPD). A recent study by Karjalainen and colleagues demonstrated
30 233 significantly increasing trends of illicit drug use among NMUPD (92% of whom had used
31 234 cannabis in the last year), that could not otherwise be explained by age or gender (19).
32 235

33 236 Important to consider in the context of the present findings is that marijuana-use trends may
34 237 not to be restricted only to states with marijuana legalization. In 2017, Hasin and colleagues
35 238 demonstrated significantly increased marijuana use both in states with and without
36 239 marijuana legalization laws (4, 7), albeit fractionally higher in states where marijuana was
37 240 legalized. However, a recent analysis by Han and colleagues demonstrated a significantly
38 241 higher trend of increasing medical-marijuana use in states without legalization (AOR 1.4, 95%
39 242 CI 1.05-1.90), compared to states with legalization (AOR 1.3, 95% CI 1.03-1.61) (14);
40 243 underlining the fact that evolving legalization laws are also of relevance to states where
41 244 recreational and medical marijuana use remains illegal.
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3 246 Exploring the economic and societal cost-effectiveness of marijuana legalization is also
4 247 important for those involved in healthcare policy and decision making. Marijuana legalization
5 248 was posited to lower price, increase availability, and thereby increase marijuana use (6), with
6 249 early fears that profit motive would take precedence over public health issues (20, 21). The
7 250 retail price of marijuana on the legal cannabis market had sharply fallen by almost 70%, just
8 251 three-years after legalization in Washington State (22, 23). Some reports described an initial
9 252 increase in self-reported street prices of marijuana in response to legalization as demand
10 253 increased, by up to 36% (24), with limited price change thereafter. However, similarly to
11 254 results aforementioned, medical legalization appears to have affected only adult marijuana
12 255 use, with minimal significant changes to adolescent use (13). While studies of the effect of
13 256 recreational marijuana legalization on its use are still emerging, there appears to be
14 257 no/minimal effect on adolescent or college marijuana use (13). The passage of legalization
15 258 laws also offers an important social justice benefit (25); by removing mechanisms for unfair,
16 259 damaging disparities in law enforcement (26). While more permissive marijuana laws may
17 260 appeal to social justice aims (reducing racial disparity in law enforcement), and increase
18 261 revenue to state and local government through taxation (6), the public health trade-offs and
19 262 overall costs of use-related adverse physical and psychosocial consequences (27) in response
20 263 to changing laws remains difficult to accurately describe (6).
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30 265 Strengths and Limitations: Strengths of our study include the size and heterogeneity of our
31 266 population, the timespan, and the age-standardization of the NHANES data. Limitations to
32 267 our study include reliance on self-reported data and reporter-bias, which may not have
33 268 affected all demographics equally. Missing data was primarily from participants who were
34 269 older and female, potentially underestimating the true prevalence of marijuana use among
35 270 this demographic. Our dataset did not include youth aged 12-17 years old, a potentially at-
36 271 risk population, nor include analysis of other risk factors associated with marijuana use (use
37 272 of tobacco, or NMUPD). Certain ethnicity data (i.e. Native American identifiers) and
38 273 geographical data (i.e. whether collected from states with or without legalization) were not
39 274 available for analysis, nor was detail of marijuana use for medicinal or recreational purposes.
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47 277 **Conclusion:**

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49 279 Our primary two findings describing characteristics of those most at risk of using marijuana,
50 280 and those where trends of use have most significantly increased, adds to the current body of
51 281 literature and understanding of marijuana trends in the United States. Given ongoing changes
52 282 to marijuana legalization in the US, with the evolving public perception of marijuana safety
53 283 and accessibility, an accurate understanding of which populations are most likely to be
54 284 implicated, which additional predictive tools can identify those most at risk, and a balanced
55 285 presentation of healthcare, social and economic costs of legalization, is warranted.
56 286 Identification of these factors can help inform the decisions of healthcare policy makers and
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3 287 professionals, and facilitate a safe transition of evolving marijuana legalization and use in the
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16 302

18 303 **Author contributions:**

20 304

21 305 Dr William Mitchell: Analysis plan, data interpretation, manuscript composition and editing,
22 306 submission, correspondence

23 307

25 308 Dr Roma Bhatia: Analysis plan, data interpretation, manuscript editing

26 309

28 310 Dr Nazlee Zebardast: Analysis plan, data extraction, analysis and interpretation, manuscript
29 311 composition

30 312

31 313

34 314 **Data Statement:**

35 315

36 316 Data is fully accessible from the following website:

37 317 <https://wwwn.cdc.gov/nchs/nhanes/default.aspx>

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Table 1: Prevalence of marijuana use in adults in the United States, NHANES 2005-2018

	2005-2006		2007-2008		2009-2010		2011-2012		2013-2014		2015-2016		2017-2018		P
	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	
Lifetime use	2922	61.5 (57.2-65.7)	3255	60.5 (57.2-63.7)	3739	57.2 (53.0-61.3)	3333	59.9 (56.0-63.6)	3690	59.2 (55.6-62.7)	3422	57.3 (53.1-61.5)	3199	60.9 (57.9-63.7)	0.53
Age <18 at First used	1617	59.6 (56.7-62.7)	1799	60.7 (58.0-63.5)	1937	62.7 (59.0-66.4)	1770	60.1 (56.0-64.0)	1984	61.4 (58.8-63.9)	1715	60.1 (56.5-63.7)	1737	61.8 (57.1-66.3)	0.68
Past-year use	2922	19.1 (15.3-23.7)	3255	19.1 (17.5-20.7)	3739	20.6 (18.2-23.3)	3333	22.4 (19.8 - 25.2)	3690	22.3 (19.9-24.8)	3422	24.9 (20.0-30.6)	3199	29.1 (26.0-32.5)	0.001

Key:

N denotes unweighted total number of participants in each category

Prevalence percentage with 95% (CI), computed using 2-year MEC weights to provide estimates for the total US population, and age-standardized to 2000 Census population.

P values test overall trend in prevalence estimates in each category

NHANES = National Health and Nutrition Examination Survey

Table 2: Prevalence of self-reported past-year marijuana use in adults in the United States, by selected demographic factors, NHANES 2005-2018

	2005-2006	2007-2008	2009-2010	2011-2012	2013-2014	2015-2016	2017-2018	P value
	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	
Age								
- 18-29	34.0 ^a (26.7-42.0)	35.1 (30.0-40.6)	34.4 (30.7-38.3)	36.2 (31.7-41.1)	38.1 (35.1-41.2)	37.3 (30.4-44.8)	46.3 (42.5-50.2)	P=0.001 ^c
- 30-49	16.1 (12.3-20.7)	16.2 (14.3-18.2)	17.5 (14.7-20.7)	17.0 (14.4-20.1)	16.3 (13.8-19.1)	21.1 (16.0-27.3)	24.6 (20.6-29.1)	P=0.001
- 50-69	10.5 (7.4-14.6) P<0.001 ^b	8.1 (6.0-10.9) P<0.001	10.3 (7.8-13.4) P<0.001	15.5 (11.4-20.8) P<0.001	14.3 (9.2-21.5) P<0.001	18.0 (13.0-23.7) P<0.001	17.0 (12.4-22.8) P<0.001	P<0.001
Gender								
- Male	24.8 (20.3-29.9)	23.1 (20.8-25.7)	24.8 (22.0-27.8)	27.3 (24.6-30.1)	26.3 (23.2-29.7)	29.2 (23.1-36.3)	32.0 (28.6-35.6)	P=0.001
- Female	13.6 (10.1-18.1) P<0.001	15.1 (13.1-17.3) P<0.001	16.3 (13.6-19.3) P<0.001	17.3 (14.0-21.2) P<0.001	18.2 (15.3-21.6) P=0.001	20.6 (16.5-25.4) P<0.001	26.3 (22.1-31.0) P=0.02	P<0.001
Race								
- NH White	20.1 (15.6-25.7)	19.4 (17.7-21.3)	21.1 (18.4-24.1)	22.7 (19.4-26.3)	22.0 (18.3-26.3)	26.7 (20.4-34.1)	30.0 (25.5-34.5)	P<0.001
- NH Black	23.56 (18.4-29.1)	26.9 (22.6-31.7)	27.6 (24.6-30.9)	27.3 (22.1-33.2)	32.9 (29.8-36.1)	32.5 (28.8-36.5)	36.8 (32.5-41.3)	P<0.001
- Hispanic/Mexican	11.7 (8.3-16.2)	13.6 (9.8-18.5)	16.6 (13.0-20.9)	18.9 (15.2-23.2)	17.9 (15.5-20.6)	16.3 (13.1-20.2)	25.0 (22.2-28.1)	P<0.001
- Other	13.2(7.9-21.2) P=0.003	13.3 (7.5-22.6) P=0.002	12.7 (7.4-21.1) P<0.001	18.7 (14.2-24.1) P=0.06	18.0 (13.7-23.3) P<0.001	19.9 (13.3-28.7) P=0.001	22.9 (18.3-28.3) P=0.002	P=0.003
Education								
- <High School	22.5 (16.5-30.0)	22.1 (17.6-27.3)	23.3 (19.5-27.6)	27.5 (22.6-33.0)	27.9 (23.6-32.6)	24.7 (20.0-30.1)	27.8 (23.3-32.8)	P=0.06
- High School	21.6 (15.1-30.0)	19.6 (17.5-21.8)	24.7 (21.2-28.5)	25.8 (20.8-31.5)	25.4 (21.1-30.3)	27.5 (22.3-33.4)	34.1 (28.1-40.6)	P<0.001
- >High School	17.4 (13.2-22.7) P=0.25	18.0 (15.4-20.8) P=0.21	18.2 (15.1-21.9) P=0.006	20.2 (17.2-23.4) P=0.01	19.8 (16.9-23.0) P=0.01	24.1 (18.2-31.3) P=0.42	27.1 (23.4-31.2) P=0.05	P<0.001
Poverty								
- >2x PL	17.7 (13.5-22.8)	16.3 (14.4-18.5)	17.1 (14.2-20.5)	18.3 (15.6-21.3)	18.5 (15.7-21.6)	22.4 (17.3-28.4)	26.3 (22.2-30.8)	P=0.001
- 1-2X PL	22.0 (16.4-28.8)	24.5 (20.8-28.6)	22.4 (18.0-27.7)	27.9 (23.8-32.3)	25.3 (21.6-29.5)	29.4 (21.8-38.4)	32.1 (28.3-36.2)	P=0.002
- < PL	24.3 (19.2-30.2) P=0.05	25.2 (19.5-32.0) P=0.001	34.6 (30.9-38.6) P<0.001	31.1 (27.1-35.4) P<0.001	33.2 (28.3-38.6) P<0.001	29.8 (23.6-37.0) P=0.004	37.0 (32.2-42.1) P=0.001	P=0.002

Key:
Prevalence percentage with 95% confidence intervals (CI), computed using 2-year interview weights to provide estimates for the total US population and are age-standardized to the US 2000 Census population.

^a percentage interpretation: of those aged 18-29, 34% reported marijuana use within the past 12 months. Poverty defined using poverty income ratio, accounting for family size

^b P values test global within group differences in prevalence

^c P values test overall trend in prevalence estimates in each category

NH = Non-Hispanic

PL = Poverty Level

NHANES = National Health and Nutrition Examination Survey

Table 3: Adjusted odds of past-year marijuana use in adults in the United States, NHANES 2005-2018

Demographic variable	Past-year marijuana use OR (95% CI)	P value
Age of participants		
- 18-29	1.0 (reference)	
- 30-49	0.39 (0.36-0.43)	P<0.001
- 50-69	0.26 (0.22-0.30)	P<0.001
Gender		
- Female	1.0 (reference)	
- Male	1.67 (1.55-1.81)	P<0.001
Race		
- Non-Hispanic White	1.0 (reference)	
- Non-Hispanic Black	1.23 (1.09-1.39)	P=0.001
- Hispanic/Mexican	0.51 (0.44-0.58)	P<0.001
- Other	0.63 (0.54-0.73)	P<0.001
Education		
- < High School	1.0 (reference)	
- High School	0.95 (0.81-1.12)	P=0.58
- > High School	0.82 (0.73-0.93)	P=0.003
Poverty		
- >2x Poverty Level	1.0 (reference)	
- 1-2X Poverty Level	1.41 (1.24-1.59)	P<0.001
- < Poverty Level	1.69 (1.49-1.92)	P<0.001
Year of survey	1.10 (1.05-1.14)	P<0.001

Key:

Odds ratio (OR) with 95% confidence intervals (CI) computed using 12-year interview weights to provide estimates for the total US population and are age-standardized to the US 2000 Census population.

Poverty defined using poverty income ratio, which accounts for family size

Year covariate modelled as a continuous variable

NHANES = National Health and Nutrition Examination Survey

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For peer review only

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item	Recommendation	Page
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	5
		(b) Describe any methods used to examine subgroups and interactions	5
		(c) Explain how missing data were addressed	5
		(d) If applicable, describe analytical methods taking account of sampling strategy	5
		(e) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5, 6
		(b) Give reasons for non-participation at each stage	-
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	5
Outcome data	15*	Report numbers of outcome events or summary measures	6
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6

		(b) Report category boundaries when continuous variables were categorized	6
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6
Discussion			
Key results	18	Summarise key results with reference to study objectives	6, 7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8
Generalisability	21	Discuss the generalisability (external validity) of the study results	8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

A Retrospective Cross-Sectional Analysis of the Changes in Marijuana Use in the United States, 2005-2018

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Primary Subject Heading:	Public health
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Keywords:	PUBLIC HEALTH, Substance misuse < PSYCHIATRY, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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3 1 **Title**
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7 3 **A Retrospective Cross-Sectional Analysis of the Changes in Marijuana Use in the United States, 2005-**
8 **2018**
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34 18 **Word count**
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36 19
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47 25 **Key words**
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51 27 Marijuana, marijuana use, drug use, illicit, legalization
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Abstract

Objectives: Understanding trends of marijuana use in the United States (US) throughout a period of particularly high adoption of marijuana-legalization, and understanding demographics most at risk of use, is important in evolving healthcare-policy and intervention. This study analyzes the demographic-specific changes in the prevalence of marijuana use in the US between 2005-2018.

Design, Setting and Participants: A fourteen-year retrospective cross-sectional analysis of the National Health and Nutrition Examination Survey (NHANES) database, a publicly-available biennially-collected national survey, weighted to represent the entire US population. A total of 35,212 adults between 18-69 years old participated in the seven-cycles of surveys analysed (2005-2018).

Primary Outcome Measured: Lifetime-use, first-use before 18-years-old, and past-year use of marijuana.

Results: The majority of adults reported ever using marijuana. While the overall prevalence of lifetime marijuana use remained stable ($p=0.53$), past-year use increased significantly between 2005-2018 ($p<0.001$) with highest rate of past-year use among younger age groups ($p<0.001$), males ($p<0.001$), and those with income below poverty level ($p<0.001$). Past-year use was commonest among non-Hispanic blacks, and less common among Hispanic/Mexican populations ($p<0.002$). Trends in past-year use increased among all age categories, males/females, all ethnicities, those with high-school education/above, and those at all income levels ($p<0.01$ for all).

Conclusions: While lifetime marijuana-use remained stable, past-year use significantly increased between 2005-2018. While past-year use remained commonest in younger age groups, males, non-Hispanic blacks and those with lower income; increasing trends in past-year use were significant for all age, sex, race and income categories, and for those with high-school education/above. With high adoption of marijuana-legalization laws during this period, our results suggest an associated increase in past-year marijuana use.

An accurate understanding of those most at risk can help inform decisions of healthcare policy makers and professionals, and facilitate a safe transition of changing marijuana legalization and use in the US.

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3 69 **Article Summary**
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- 6 71 - This is the most recent study of trends of marijuana use in the United States, during a
7 72 period of particularly high rates of adoption of marijuana legalization laws.
8
9 73 - The National Health and Nutrition Examination Survey (NHANES) database is a
10 74 publicly-available and nation-wide database. The NHANES database is weighted
11 75 (standardized), to accurately represent the entire population of the United States.
12
13 76 - The NHANES database is self-reported, and limited by reporter bias.
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15 77 - Missing data was primarily from participants who were older and female, potentially
16 78 underestimating the true prevalence of marijuana use among this demographic.
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18 79 - State-based legalization information and use amongst adolescents less than 18-years-
19 80 old was not available, and could not be accurately correlated with changing trends of
20 81 marijuana use.
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85 Introduction:

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87 While remaining illegal at the federal level in the United States (US), marijuana is now legal
88 for recreational use by adults over the age of 21 in 11 states, and for medical use in 33 states
89 (1, 2). With particularly high adoption rates of medical marijuana legalization between 2007
90 and 2016 (3), and increasing social acceptability of marijuana use (4-6), describing trends in
91 use among different demographics in the US is important in understanding which populations
92 might be most affected by changing laws.

93

94 Prior studies have described increases in both marijuana use and misuse trends since medical
95 marijuana legalisation (4, 7, 8) in marijuana users both domestically and overseas (9).
96 However, some studies have shown no changes to trends of past-year use since legalisation
97 (10, 11), and others have shown only increases in marijuana misuse (11). A recent analysis
98 even described a significant decrease in marijuana misuse disorder since legalisation (12).
99 There have also been inconsistent reports of the demographics of those most affected by
100 changing medical and recreational marijuana legalisation; some studies describing increasing
101 trends across all gender, age and ethnic demographics (7), some showing trend changes
102 particularly for young, black, and Hispanic men (11), and others showing changes particularly
103 among older individuals (4, 6, 13). Importantly, changing trends in medical and non-medical
104 marijuana use do not appear to be restricted only to states with changing marijuana laws (14),
105 despite being higher in states where laws have been passed (7). An understanding of both the
106 social and the economic cost-effectiveness of legalising marijuana (15, 16), coupled with an
107 understanding of trends of changing use, may be useful for those working in public health,
108 public policy, and healthcare, responsible for policy intervention or caring for populations
109 most affected by marijuana use.

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111 The current paper uses data from the US National Health and Nutrition Examination Survey
112 (NHANES), a nationally-representative sample of US adults, to examine the most recent 12-
113 year trends in marijuana use in the United States. Additionally, we examine sociodemographic
114 factors associated with marijuana use. We explore recent literature regarding the cost-
115 effectiveness of medical and social marijuana legalization, adding to the current body of
116 literature important for those in policy, or caring for those most affected.

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119 Methods:

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121 The National Health and Nutrition Examination Survey (NHANES) is an on-going biennial
122 cross-sectional survey representing a non-institutionalized civilian US population, performed
123 by the National Centre for Health Statistics (NCHS) and Centres for Disease Control and

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3 124 Prevention (CDC). NHANES has been a continuous survey program providing health statistics
4 125 for the US since 1999, examining a nationally-representative sample of about 5,000 people
5 126 each year, located in counties across the US. Study teams consisting of multilingual physicians,
6 127 medical and health technicians, and dietary health interviewers conduct interviews and
7 128 perform examinations, and information collected is intended to be used to determine the
8 129 prevalence of major diseases and risk factors for diseases, and for health promotion and
9 130 disease prevention; making NHANES an ideal data source to describe marijuana use trends in
10 131 a nationally-representative population. The sample for the survey is selected to represent the
11 132 US population of all ages. To produce reliable statistics, NHANES over-samples persons 60 and
12 133 older, African Americans, and Hispanics (17).
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19 135 In the present study, seven two-year cycles of NHANES survey data between 2005-2018
20 136 (inclusive) have been retrospectively analysed for baseline demographic information, and
21 137 drug use questionnaire data. A total of 35,212 adults (US citizens) between 18-69 years old
22 138 participated in the seven-cycles of surveys analysed. Of these, 32.9% had missing marijuana
23 139 survey data. Those with missing data were significantly more likely to be older ($p<0.001$),
24 140 female ($p<0.001$) and have less than high school education ($p<0.001$). Missing data was
25 141 handled by pairwise deletion to optimize data available for analysis. Participants undergo a
26 142 home interview, and a comprehensive physical examination in a mobile examination centre
27 143 (MEC). The 2005-2018 NHANES protocol was approved by the National Centre for Health
28 144 Statistics research ethics review board and written informed consent obtained from all
29 145 participants.
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35 147 Demographics data including age, gender, race/ethnicity, education and income were
36 148 collected during the home interview. The drug use questionnaire was conducted in the mobile
37 149 examination centre (MEC), and aimed to assess lifetime, past-year, and current usage of
38 150 marijuana. Questions are self-administered using the Audio Computer-Assisted Self-Interview
39 151 (ACASI) system. The ACASI was conducted in English, Spanish, Korean, Vietnamese, or Chinese
40 152 (Mandarin and Cantonese). Participants reported lifetime use, age at first use and use within
41 153 the past-year of marijuana.
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47 155 Given the NHANES complex probability sampling design, 2-year interview weights computed
48 156 by the NCHS were used to calculate prevalence estimates and 95% confidence intervals
49 157 (Taylor linearization), age-standardized to the 2000 US Census population as recommended
50 158 by the NCHS. Differences in prevalence estimates were compared using chi-square tests.
51 159 Univariate regression models were used to test for significant linear trends while
52 160 multivariable regression models were used to determine characteristics associated with
53 161 recent marijuana use. Results at the $p<0.05$ level considered statistically significant. Statistical
54 162 analysis was performed using STATA version 15.0 (StataCorp LP, College Station, TX).
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3 164 Patient and public involvement: Patients or the public were not involved in the development
4 165 of the research question or study design, in the measurement of the outcomes, or in the
5 166 dissemination of results for the present study.
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9 168 **Results:**

10 169
11 170 Overall, 53.5% (95% CI 52.8-54.1%) of the US adult population reported ever using marijuana
12 171 between 2005-2018. The prevalence of lifetime marijuana use, and first use before the age
13 172 of 18, remained stable between 2005 and 2018 ($p=0.53$ and $p=0.68$, respectively) (Table 1).
14 173 Overall 22.6% (95% CI 22.1-23.1%) of US adults reported using marijuana within the last year.
15 174 The weighted prevalence of past-year marijuana use increased significantly during the study
16 175 period from 19.1% (95% CI 15.3-23.7%) in 2005/06 to 29.1% (95% CI 26.0-32.5%) ($p=0.001$) in
17 176 2017/18.
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22 178 The prevalence of past-year marijuana use was higher among younger age groups ($p<0.001$),
23 179 males ($p<0.05$), and those with income below poverty level ($p<0.05$) (Table 2). Past-year
24 180 marijuana use was more common among non-Hispanic blacks, and less common among
25 181 Hispanic/Mexicans ($p<0.002$ (excluding 2011/12 and 2017/18)). Between 2005 - 2018 the
26 182 prevalence of past-year marijuana use increased among all age categories ($p<0.001$), males
27 183 and females ($p<0.001$), all racial categories ($p<0.01$ for all groups), those with high school
28 184 education or above ($p<0.001$ for both) and those at all levels of income ($p<0.01$).
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31 186 Multivariate logistic regression analysis demonstrated higher odds of past-year marijuana use
32 187 among younger age groups ($p<0.001$), males ($p<0.001$), non-Hispanic blacks ($p<0.001$), and
33 188 those with income below the poverty level ($p<0.001$ for both) (Table 3). Past-year use was
34 189 less likely among older individuals ($p<0.001$), and Hispanic and Mexican Americans ($p<0.001$)
35 190 and those with higher levels of education ($p=0.003$) (Table 3).
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44 193 **Discussion:**

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46 195 The current study presents the most recent changes in marijuana use in the US during a period
47 196 of particularly high legalization. It finds that while lifetime marijuana use, and first-use before
48 197 the age of 18, has remained stable, the overall prevalence of past-year marijuana use has
49 198 significantly increased over the 14-year period. While past-year use was still more common
50 199 among younger age groups, males, non-Hispanic blacks and those with lower income,
51 200 significant trends of increasing past-year use were seen in all age categories, males and
52 201 females, all racial categories, highly-educated populations, and all income levels. Age-specific
53 202 marijuana use trends in response to legalization laws has been studied elsewhere; but with
54 203 inconsistent findings. There has been growing consensus that increasing recent-use of
55 204 marijuana is seen among late to middle-aged adults after legalization (6, 13); a recent study
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3 205 by Salas-Wright and colleagues showing trends of increasing past-year use among late to
4 206 middle-aged adults in the US between 2002-2014 (5), findings that are supported by the
5 207 present study. Whether this pattern of recent-use among older populations is associated with
6 208 increasing marijuana-use for medicinal purposes (seen most prominently among older, white,
7 209 male, and high-income populations in the US) (14), is unclear, and such data was not available
8 210 for analysis in the present study. However, there has been less consensus about recent-use
9 211 trends among adolescent populations. While a comprehensive study by Harpin and
10 212 colleagues described no change in adolescent-use after legalization (10) (further supported
11 213 by more recent findings (6)), a 2019 review by Bae and colleagues described increasing recent-
12 214 use amongst adolescents in the US after legalization (8). Contrastingly, a 2016 US study by
13 215 Grucza and colleagues describes that past-year marijuana use actually *decreased* among
14 216 adolescents, during the highest periods of legalization (12). Information about marijuana-use
15 217 trends in adolescents less than 18-years-old was not publicly available on NHANES for the
16 218 present study, but it has been noted that over the 14-year study period, there has been no
17 219 significant change in reported first-use before the age of 18 (table 1).
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26 221 Our findings of younger, male, non-Hispanic black and lower income populations being most
27 222 likely to use marijuana overall, are also consistent with previous findings not aforementioned
28 223 (4, 7). Native American populations, those living in urban areas, and those living in western
29 224 states, have also been shown to be more likely to have recently used marijuana; but this
30 225 information was not available on NHANES in sufficient detail, for the present analyses.
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34 227 In addition to demographic risk factors indicating potential marijuana use, an understanding
35 228 of other risk factors is important for those involved in fields of public policy and healthcare.
36 229 While age and gender remain somewhat inconsistently described risk factors, tobacco
37 230 smoking is a demonstrated risk factor for marijuana use. Though not analyzed in the present
38 231 study, a recent study demonstrated that current smokers have almost 6x increased odds of
39 232 recent marijuana use compared to non-smokers (18), outlining another sub-population
40 233 particularly at risk. Another group at risk of increasing marijuana use are non-medical users
41 234 of prescription drugs (NMUPD). A recent study by Karjalainen and colleagues demonstrated
42 235 significantly increasing trends of illicit drug use among NMUPD (92% of whom had used
43 236 cannabis in the last year), that could not otherwise be explained by age or gender (19).
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50 238 Important to consider in the context of the present findings is that marijuana-use trends may
51 239 not to be restricted only to states with marijuana legalization. In 2017, Hasin and colleagues
52 240 demonstrated significantly increased marijuana use both in states with and without
53 241 marijuana legalization laws (4, 7), albeit fractionally higher in states where marijuana was
54 242 legalized. However, a recent analysis by Han and colleagues demonstrated a significantly
55 243 higher trend of increasing medical-marijuana use in states without legalization (AOR 1.4, 95%
56 244 CI 1.05-1.90), compared to states with legalization (AOR 1.3, 95% CI 1.03-1.61) (14);
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3 245 underlining the fact that evolving legalization laws are also of relevance to states where
4 246 recreational and medical marijuana use remains illegal.

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7 248 Exploring the economic and societal cost-effectiveness of marijuana legalization is also
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9 249 important for those involved in healthcare policy and decision making. Marijuana legalization
10 250 was posited to lower price, increase availability, and thereby increase marijuana use (6), with
11 251 early fears that profit motive would take precedence over public health issues (20, 21). The
12 252 retail price of marijuana on the legal cannabis market had sharply fallen by almost 70%, just
13 253 three-years after legalization in Washington State (22, 23). Some reports described an initial
14 254 increase in self-reported street prices of marijuana in response to legalization as demand
15 255 increased, by up to 36% (24), with limited price change thereafter. However, similarly to
16 256 results aforementioned, medical legalization appears to have affected only adult marijuana
17 257 use, with minimal significant changes to adolescent use (13). While studies of the effect of
18 258 recreational marijuana legalization on its use are still emerging, there appears to be
19 259 no/minimal effect on adolescent or college marijuana use (13). The passage of legalization
20 260 laws also offers an important social justice benefit (25); by removing mechanisms for unfair,
21 261 damaging disparities in law enforcement (26). While more permissive marijuana laws may
22 262 appeal to social justice aims (reducing racial disparity in law enforcement), and increase
23 263 revenue to state and local government through taxation (6), the public health trade-offs and
24 264 overall costs of use-related adverse physical and psychosocial consequences (27) in response
25 265 to changing laws remains difficult to accurately describe (6).

26 266
27 267 Strengths and Limitations: Strengths of our study include the size and heterogeneity of our
28 268 population, the timespan, and the age-standardization of the NHANES data. Limitations to
29 269 our study include reliance on self-reported data and reporter-bias, which may not have
30 270 affected all demographics equally. Missing data was primarily from participants who were
31 271 older and female, potentially underestimating the true prevalence of marijuana use among
32 272 this demographic. Our dataset did not include youth aged 12-17 years old, a potentially at-
33 273 risk population, nor include analysis of other risk factors associated with marijuana use (use
34 274 of tobacco, or NMUPD). Certain ethnicity data (i.e. Native American identifiers) and
35 275 geographical data (i.e. whether collected from states with or without legalization) were not
36 276 available for analysis, nor was detail of marijuana use for medicinal or recreational purposes.

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38 278

39 279 **Conclusion:**

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41 281 Our primary two findings describing characteristics of those most at risk of using marijuana,
42 282 and those where trends of use have most significantly increased, adds to the current body of
43 283 literature and understanding of marijuana trends in the United States. Given ongoing changes
44 284 to marijuana legalization in the US, with the evolving public perception of marijuana safety
45 285 and accessibility, an accurate understanding of which populations are most likely to be

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3 286 implicated, which additional predictive tools can identify those most at risk, and a balanced
4 287 presentation of healthcare, social and economic costs of legalization, is warranted.
5 288 Identification of these factors can help inform the decisions of healthcare policy makers and
6 289 professionals, and facilitate a safe transition of evolving marijuana legalization and use in the
7 290 US.
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3 294 **Author statements:**

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6 296 There are no competing or conflicting interests to declare by any of the authors.

7 297

8 298

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16 303

17 304

18 305 **Author contributions:**

20 306

21 307 Dr William Mitchell: Analysis plan, data interpretation, manuscript composition and editing,
22 308 submission, correspondence

24 309

25 310 Dr Roma Bhatia: Analysis plan, data interpretation, manuscript editing

27 311

28 312 Dr Nazlee Zebardast: Analysis plan, data extraction, analysis and interpretation, manuscript
29 313 composition

31 314

32 315

34 316 **Data Statement:**

35 317

36 318 Data is fully accessible from the following website:

38 319 <https://wwwn.cdc.gov/nchs/nhanes/default.aspx>

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Table 1: Prevalence of marijuana use in adults in the United States, NHANES 2005-2018

	2005-2006		2007-2008		2009-2010		2011-2012		2013-2014		2015-2016		2017-2018		P
	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	Total N	Prevalence % (95% CI)	
Lifetime use	2922	61.5 (57.2-65.7)	3255	60.5 (57.2-63.7)	3739	57.2 (53.0-61.3)	3333	59.9 (56.0-63.6)	3690	59.2 (55.6-62.7)	3422	57.3 (53.1-61.5)	3199	60.9 (57.9-63.7)	0.53
Age <18 at First used	1617	59.6 (56.7-62.7)	1799	60.7 (58.0-63.5)	1937	62.7 (59.0-66.4)	1770	60.1 (56.0-64.0)	1984	61.4 (58.8-63.9)	1715	60.1 (56.5-63.7)	1737	61.8 (57.1-66.3)	0.68
Past-year use	2922	19.1 (15.3-23.7)	3255	19.1 (17.5-20.7)	3739	20.6 (18.2-23.3)	3333	22.4 (19.8 - 25.2)	3690	22.3 (19.9-24.8)	3422	24.9 (20.0-30.6)	3199	29.1 (26.0-32.5)	0.001

Key:

N denotes unweighted total number of participants in each category

Prevalence percentage with 95% (CI), computed using 2-year MEC weights to provide estimates for the total US population, and age-standardized to 2000 Census population.

P values test overall trend in prevalence estimates in each category

NHANES = National Health and Nutrition Examination Survey

Table 2: Prevalence of self-reported past-year marijuana use in adults in the United States, by selected demographic factors, NHANES 2005-2018

	2005-2006	2007-2008	2009-2010	2011-2012	2013-2014	2015-2016	2017-2018	P value
	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	Prevalence % (95% CI)	
Age								
- 18-29	34.0 ^a (26.7-42.0)	35.1 (30.0-40.6)	34.4 (30.7-38.3)	36.2 (31.7-41.1)	38.1 (35.1-41.2)	37.3 (30.4-44.8)	46.3 (42.5-50.2)	P=0.001 ^c
- 30-49	16.1 (12.3-20.7)	16.2 (14.3-18.2)	17.5 (14.7-20.7)	17.0 (14.4-20.1)	16.3 (13.8-19.1)	21.1 (16.0-27.3)	24.6 (20.6-29.1)	P=0.001
- 50-69	10.5 (7.4-14.6) P<0.001 ^b	8.1 (6.0-10.9) P<0.001	10.3 (7.8-13.4) P<0.001	15.5 (11.4-20.8) P<0.001	14.3 (9.2-21.5) P<0.001	18.0 (13.0-23.7) P<0.001	17.0 (12.4-22.8) P<0.001	P<0.001
Gender								
- Male	24.8 (20.3-29.9)	23.1 (20.8-25.7)	24.8 (22.0-27.8)	27.3 (24.6-30.1)	26.3 (23.2-29.7)	29.2 (23.1-36.3)	32.0 (28.6-35.6)	P=0.001
- Female	13.6 (10.1-18.1) P<0.001	15.1 (13.1-17.3) P<0.001	16.3 (13.6-19.3) P<0.001	17.3 (14.0-21.2) P<0.001	18.2 (15.3-21.6) P=0.001	20.6 (16.5-25.4) P<0.001	26.3 (22.1-31.0) P=0.02	P<0.001
Race								
- NH White	20.1 (15.6-25.7)	19.4 (17.7-21.3)	21.1 (18.4-24.1)	22.7 (19.4-26.3)	22.0 (18.3-26.3)	26.7 (20.4-34.1)	30.0 (25.5-34.5)	P<0.001
- NH Black	23.56 (18.4-29.1)	26.9 (22.6-31.7)	27.6 (24.6-30.9)	27.3 (22.1-33.2)	32.9 (29.8-36.1)	32.5 (28.8-36.5)	36.8 (32.5-41.3)	P<0.001
- Hispanic/Mexican	11.7 (8.3-16.2)	13.6 (9.8-18.5)	16.6 (13.0-20.9)	18.9 (15.2-23.2)	17.9 (15.5-20.6)	16.3 (13.1-20.2)	25.0 (22.2-28.1)	P<0.001
- Other	13.2(7.9-21.2) P=0.003	13.3 (7.5-22.6) P=0.002	12.7 (7.4-21.1) P<0.001	18.7 (14.2-24.1) P=0.06	18.0 (13.7-23.3) P<0.001	19.9 (13.3-28.7) P=0.001	22.9 (18.3-28.3) P=0.002	P=0.003
Education								
- <High School	22.5 (16.5-30.0)	22.1 (17.6-27.3)	23.3 (19.5-27.6)	27.5 (22.6-33.0)	27.9 (23.6-32.6)	24.7 (20.0-30.1)	27.8 (23.3-32.8)	P=0.06
- High School	21.6 (15.1-30.0)	19.6 (17.5-21.8)	24.7 (21.2-28.5)	25.8 (20.8-31.5)	25.4 (21.1-30.3)	27.5 (22.3-33.4)	34.1 (28.1-40.6)	P<0.001
- >High School	17.4 (13.2-22.7) P=0.25	18.0 (15.4-20.8) P=0.21	18.2 (15.1-21.9) P=0.006	20.2 (17.2-23.4) P=0.01	19.8 (16.9-23.0) P=0.01	24.1 (18.2-31.3) P=0.42	27.1 (23.4-31.2) P=0.05	P<0.001
Poverty								
- >2x PL	17.7 (13.5-22.8)	16.3 (14.4-18.5)	17.1 (14.2-20.5)	18.3 (15.6-21.3)	18.5 (15.7-21.6)	22.4 (17.3-28.4)	26.3 (22.2-30.8)	P=0.001
- 1-2X PL	22.0 (16.4-28.8)	24.5 (20.8-28.6)	22.4 (18.0-27.7)	27.9 (23.8-32.3)	25.3 (21.6-29.5)	29.4 (21.8-38.4)	32.1 (28.3-36.2)	P=0.002
- < PL	24.3 (19.2-30.2) P=0.05	25.2 (19.5-32.0) P=0.001	34.6 (30.9-38.6) P<0.001	31.1 (27.1-35.4) P<0.001	33.2 (28.3-38.6) P<0.001	29.8 (23.6-37.0) P=0.004	37.0 (32.2-42.1) P=0.001	P=0.002

Key:
Prevalence percentage with 95% confidence intervals (CI), computed using 2-year interview weights to provide estimates for the total US population and are age-standardized to the US 2000 Census population.

^a percentage interpretation: of those aged 18-29, 34% reported marijuana use within the past 12 months. Poverty defined using poverty income ratio, accounting for family size

^b P values test global within group differences in prevalence

^c P values test overall trend in prevalence estimates in each category

NH = Non-Hispanic

PL = Poverty Level

NHANES = National Health and Nutrition Examination Survey

Table 3: Adjusted odds of past-year marijuana use in adults in the United States, NHANES 2005-2018

Demographic variable	Past-year marijuana use OR (95% CI)	P value
Age of participants		
- 18-29	1.0 (reference)	
- 30-49	0.39 (0.36-0.43)	P<0.001
- 50-69	0.26 (0.22-0.30)	P<0.001
Gender		
- Female	1.0 (reference)	
- Male	1.67 (1.55-1.81)	P<0.001
Race		
- Non-Hispanic White	1.0 (reference)	
- Non-Hispanic Black	1.23 (1.09-1.39)	P=0.001
- Hispanic/Mexican	0.51 (0.44-0.58)	P<0.001
- Other	0.63 (0.54-0.73)	P<0.001
Education		
- < High School	1.0 (reference)	
- High School	0.95 (0.81-1.12)	P=0.58
- > High School	0.82 (0.73-0.93)	P=0.003
Poverty		
- >2x Poverty Level	1.0 (reference)	
- 1-2X Poverty Level	1.41 (1.24-1.59)	P<0.001
- < Poverty Level	1.69 (1.49-1.92)	P<0.001
Year of survey	1.10 (1.05-1.14)	P<0.001

Key:

Odds ratio (OR) with 95% confidence intervals (CI) computed using 12-year interview weights to provide estimates for the total US population and are age-standardized to the US 2000 Census population.

Poverty defined using poverty income ratio, which accounts for family size

Year covariate modelled as a continuous variable

NHANES = National Health and Nutrition Examination Survey

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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item	Recommendation	Page
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	5
		(b) Describe any methods used to examine subgroups and interactions	5
		(c) Explain how missing data were addressed	5
		(d) If applicable, describe analytical methods taking account of sampling strategy	5
		(e) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5, 6
		(b) Give reasons for non-participation at each stage	-
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	5
Outcome data	15*	Report numbers of outcome events or summary measures	6
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6

		(b) Report category boundaries when continuous variables were categorized	6
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6
Discussion			
Key results	18	Summarise key results with reference to study objectives	6, 7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8
Generalisability	21	Discuss the generalisability (external validity) of the study results	8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.