

## Relationship between Years of Marijuana Use and the Four Main Diagnostic Criteria for Metabolic Syndrome among United States Adults

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### Abstract

**Objective:** Research on marijuana use suggests a protective effect on metabolic syndrome. National Cholesterol Education Program, Adult Treatment Panel III, World Health Organization, European Group for the study of Insulin Resistance and International Diabetes Federation have different criteria for metabolic syndrome. Definitions of both marijuana use and criteria for metabolic syndrome may influence the observed effects. We examine the relationship of years of marijuana use with the four common definitions of metabolic syndrome.

**Method:** This is a cross-sectional study of 3051 adults aged  $\geq 20$  years who participated in the National Health and Nutrition Examination Survey 2011-2012. Only participants who responded to the question, "Have you ever even once used marijuana or hashish?" were enrolled. Using multivariate logistic regression, we estimated odds ratios for metabolic syndrome with each year of marijuana use.

**Results:** Adjusted odds ratios (AOR) for having metabolic syndrome with each increase in year of marijuana use was 1.05 (95% CI: 1.02, 1.08) using National Cholesterol Education Program Adult Treatment Panel III (ATP III) criteria. Respective AOR using International Diabetes Federation (IDF) was 1.08 (95% CI: 1.04, 1.13) and 1.05 (95% CI: 1.04, 1.13) using World Health Organization (WHO) or European Group for the study of Insulin Resistance (EGIR) criteria. Using ATP III or IDF criteria, the adjusted odds ratio of having hypertension (AOR Hyp) for each year of marijuana use was 1.07 (95% CI: 1.03, 1.12). Using WHO criteria, AOR Hyp was 1.05 (95% CI: 1.01, 1.09) and 1.08 (95% CI: 1.03, 1.12) using EGIR. All the applicable criteria show increased odds for abdominal obesity: AOR 1.06 (95% CI: 1.00, 1.11) (ATP III), 1.09 (95% CI: 1.05, 1.14) (EGIR) or 1.07 (95% CI: 1.01, 1.13) (IDF). Adjusted odds ratio for having high oral glucose tolerance test levels was 1.12 (95% CI: 1.07, 1.18) using WHO and EGIR criteria.

**Conclusion:** Irrespective of the criteria for metabolic syndrome, each year of marijuana use showed increased odds of having metabolic syndrome, hypertension or high oral glucose tolerance test levels. This increased odd is in contrast to most findings in literature. The small, yet consistent increase in odds for hypertension was slightly higher than that observed with cigarette smoking. Recreational marijuana use may be detrimental to cardiovascular health. A standardized definition of marijuana use will be relevant for further investigation.

**Keywords:** Cannabis; Cardiovascular disease; Cigarette; Marijuana; Metabolic syndrome; Tobacco

### Introduction

Marijuana is a psychoactive substance that induces relaxation and euphoria. Marijuana is classified as a schedule 1 drug by the drug enforcement administration (DEA) and is an illicit compound under federal law. However, by the end of election 2016, 28 states had legalized medical marijuana. Eight states and Washington DC also permit adult recreational marijuana use. Support for legalization of marijuana is on ascendancy [1]. Like cigarette, the main route of administration of marijuana is smoking and whereas the detrimental

effect of tobacco/cigarette on cardiovascular health is established, that of marijuana is unknown.

Metabolic syndrome (MetS) is a constellation of cardiovascular risk factors and is a condition associated with detrimental cardiovascular prognosis. Because cardiovascular disease (CVD) is a leading cause of mortality worldwide [2], the prevalence of metabolic syndrome may be an important determinant of the health status of a nation. The prevalence of metabolic syndrome generally increases with age. During the period 2003 to 2012, metabolic syndrome prevalence in the United States (US) was about 18.0% among adults aged 20-39 years, 35.0% among adults aged 40-59 years and 46.7% among adults aged 60 years and above [3]. In 2012, an estimated 31.0% of all global deaths were due to CVDs [4]. Studies on tobacco and marijuana are inconclusive

on their associations with metabolic syndrome and its components [2,5]. Metabolic syndrome has varying criteria. National Cholesterol Education Program, Adult Treatment Panel III (ATP), World Health Organization (WHO), European Group for the study of Insulin Resistance (EGIR) and International Diabetes Federation (IDF) have different criteria for metabolic syndrome. Definitions of both

marijuana use and criteria for metabolic syndrome may influence the observed effects. We examine the relationship of years of marijuana use with the four common definitions of metabolic syndrome. Our hypothesis is that the definition used for metabolic syndrome may change the estimates of the associations between marijuana use and metabolic syndrome.

| Variable                    | Sample Size (%) | Race  |       |       |       |        |       |
|-----------------------------|-----------------|-------|-------|-------|-------|--------|-------|
|                             |                 | NHW   | NHB   | MA    | OHISP | ASIANS | ORACE |
| <b>Marijuana Use***</b>     |                 |       |       |       |       |        |       |
| Never                       | 1427 (46.80)    | 33.78 | 42.86 | 61.09 | 58.72 | 73.30  | 33.56 |
| Non-regular                 | 824 (27.03)     | 33.51 | 25.66 | 23.10 | 21.71 | 18.74  | 28.70 |
| Regular                     | 798 (26.17)     | 32.7  | 31.48 | 15.81 | 19.57 | 7.60   | 40.74 |
| <b>Cigarette smoking***</b> |                 |       |       |       |       |        |       |
| Never                       | 1807 (59.25)    | 48.43 | 63.26 | 64.13 | 62.63 | 74.94  | 55.56 |
| Past                        | 510 (16.72)     | 20.49 | 11.74 | 19.15 | 19.22 | 13.11  | 14.81 |
| Current                     | 733 (24.03)     | 31.09 | 25.00 | 16.72 | 18.15 | 11.94  | 29.63 |
| <b>Gender*</b>              |                 |       |       |       |       |        |       |
| Male                        | 1552 (50.87)    | 52.02 | 46.66 | 54.71 | 48.04 | 53.40  | 55.56 |
| Female                      | 1499 (49.13)    | 47.98 | 53.34 | 45.29 | 51.96 | 46.60  | 44.44 |
| <b>Marital Status***</b>    |                 |       |       |       |       |        |       |
| Married                     | 1371 (44.94)    | 49.15 | 31.65 | 52.28 | 41.28 | 56.91  | 38.89 |
| Other                       | 1680 (55.06)    | 50.85 | 68.35 | 47.72 | 58.72 | 43.09  | 61.11 |
| <b>Country of Birth***</b>  |                 |       |       |       |       |        |       |
| USA                         | 2154 (70.65)    | 95.06 | 89.91 | 41.77 | 26.79 | 19.67  | 80.56 |
| Other Countries             | 895 (29.35)     | 4.94  | 10.09 | 58.23 | 73.21 | 80.33  | 19.44 |
| <b>Education***</b>         |                 |       |       |       |       |        |       |
| ≤ High School Graduate      | 1172 (38.41)    | 33.42 | 38.97 | 69.6  | 52.31 | 19.44  | 29.63 |
| ≥ Some College              | 1879 (61.59)    | 68.58 | 61.03 | 30.6  | 47.69 | 80.56  | 70.37 |
| <b>Age groups (Years)**</b> |                 |       |       |       |       |        |       |
| 20-25                       | 543 (17.80)     | 15.09 | 20.43 | 15.50 | 17.08 | 19.44  | 28.70 |
| Above 25                    | 2508 (82.20)    | 84.91 | 79.57 | 84.50 | 82.92 | 80.56  | 71.30 |
| <b>PIR***</b>               |                 |       |       |       |       |        |       |
| <1.00                       | 753 (26.39)     | 24.91 | 31.12 | 30.95 | 30.15 | 15.56  | 27.18 |
| 1.00 to 2.99                | 1048 (36.73)    | 36.02 | 36.93 | 42.52 | 43.13 | 29.16  | 38.83 |
| 3.00 to 4.99                | 555 (19.45)     | 19.26 | 19.09 | 18.03 | 17.94 | 24.04  | 14.56 |
| >5.00                       | 497 (17.42)     | 19.81 | 12.86 | 8.50  | 8.78  | 31.20  | 19.42 |
| <b>Other Drug Use***</b>    |                 |       |       |       |       |        |       |
| No                          | 2504 (82.23)    | 74.41 | 87.01 | 80.49 | 87.14 | 94.6   | 71.30 |
| Yes                         | 541 (17.77)     | 25.59 | 12.99 | 19.51 | 12.86 | 5.40   | 28.70 |

| Ever had rehabilitation*** |              |       |       |       |       |       |       |  |
|----------------------------|--------------|-------|-------|-------|-------|-------|-------|--|
| No                         | 2877 (94.30) | 92.54 | 92.18 | 97.57 | 96.44 | 99.30 | 92.59 |  |
| Yes                        | 174 (5.70)   | 7.46  | 7.82  | 2.43  | 3.56  | 0.70  | 7.41  |  |

**Table 1a:** Proportions of recreational substance use and demographic characteristics of participants stratified by race, Percentages are column percentages. Chi square tests (\*P<0.05, \*\*P<0.01, \*\*\*P<0.001) show significant differences among the various racial ethnic groups. MA: Mexican Americans; NHW: Non-Hispanic Whites; NHB: Non-Hispanic Blacks; OHISP: Other Hispanics; ORACE: Other Race or Multiracial; PIR: Family Income to Poverty Ratio.

## Literature Review

Metabolic syndrome is a co-occurrence of hypertension, hyperlipidemia, hyperglycemia and visceral obesity. Metabolic syndrome is associated with cardiometabolic pathology [6]. There is no unified definition [7,8] for MetS, however, the definition by the National Cholesterol Education Program, Adult Treatment Panel III (ATP III) is widely adopted because of its clinical applicability [8]. In accordance with ATP III, MetS is a co-occurrence of any three of the following: Hypertension, hyperglycemia, abdominal obesity, reduced high density lipoprotein cholesterol (HDL-C) or hypertriglyceridemia. By WHO standard, MetS is a diagnosis of diabetes or increased two hour oral glucose tolerance test (OGTT) or fasting insulin levels plus any two or more of the following: hypertension, obesity, high plasma triglycerides, low plasma HDL-C or albumin creatinine ratio  $\geq 30$ . By EGIR criteria, MetS consists of fasting insulin level above 75th percentile of cohorts, and two or more of the following: hypertension, abdominal obesity, hypertriglyceridemia or low HDL-C. The IDF criteria require increases in ethnicity-specific waist circumference and any two or more of the following: hypertension, hypertriglyceridemia, low plasma HDL-C and high fasting plasma glucose or diagnosis of diabetes [8].

Results from research on marijuana use and MetS suggest a protective effect of marijuana use for MetS and some of its components [5,9]. Although some therapeutic effects of extracts of cannabis (marijuana plant) can be anticipated [10], these benefits may not apply to recreational use of marijuana. In the US, tobacco and marijuana are the most common substances of abuse after alcohol [11]. Statistics from the 2014 National Survey of Drug Use and Health, under the Substance Abuse and Mental Health Services Administration, show that among US adults aged 18-25 years, the lifetime prevalence of alcohol, cigarette and marijuana use were 83.4%, 56.1% and 52.6%, respectively whilst among US adults aged 26 years and above, lifetime prevalence were 88.3%, 67.5% and 46.1%, respectively [12]. With a likely increase in marijuana use arising from legalization of marijuana, it is important to assess the relationship with determinants of cardiovascular disease.

## Method

### Data and variables

This is a cross-sectional study of adults aged 20 years and above who participated in the National Health and Nutrition Examination Survey (NHANES) 2011-2012. Only participants who responded to the question, "Have you ever even once used marijuana or hashish?" were enrolled.

Dependent variable: Our main dependent variable was MetS. We used the four most widely accepted definitions of MetS. In accordance with 2005 modification of ATP III criteria for MetS, we classified participants as having MetS if they had a co-occurrence of three or more of the following: Hypertension-an average blood pressure  $>130/85$  mm Hg or use of medication for hypertension; Hyperglycemia-defined as fasting plasma glucose (FBG)  $\geq 100$  mg/dl or use of medication for diabetes; Abdominal obesity or high waist circumference-defined as females with waist circumference  $>88.0$  cm and males with waist circumference  $>102.0$  cm; Low HDL cholesterolemia-defined as plasma HDL-C levels  $<50$  mg/dl for females and  $<40$  mg/dl for males or use of medications for hypercholesterolemia; and Hypertriglyceridemia-defined as plasma triglycerides  $\geq 150$  mg/dl or use of medication for hypercholesterolemia. Details of laboratory and clinical procedures are described in the NHANES manual.

By WHO criteria, participants who said they had been diagnosed with diabetes by a doctor or were using medications for diabetes, or had a two hour oral glucose tolerance test (OGTT) result  $\geq 140$  mg/dl, or fasting insulin levels  $>25.2$   $\mu$ IU/ml and had any two or more of the following: average blood pressure  $140/90$  mmHg; body mass index  $>30$   $\text{kg}/\text{m}^2$ ; plasma triglycerides  $150$  mg/dl; plasma HDL-C levels  $<39$  mg/dl (for females) or  $<35$  mg/dl (for males); and albumin creatinine ratio  $30$ .

By EGIR criteria, participants whose fasting insulin level fell above 75th percentile of this study group and had two or more of the following: average blood pressure  $\geq 140/90$  mm Hg or use of medications for hypertension; waist circumference  $\geq 94$  cm if male or  $\geq 80$  cm if female; plasma triglyceride  $\geq 150$  mg/dl; HDL-C  $\geq 39$  mg/dl.

By IDF criteria, ethnicity-specific waist circumference being  $\geq 94$  cm (for black males) or  $\geq 80$  cm (for black females);  $\geq 102$  cm (for white males) or  $\geq 88$  cm (for white female), and  $\geq 94$  cm or  $\geq 80$  cm for males and females respectively who were Asians/Mexican American/Multiracial and had any two or more of the following: average blood pressure  $>130/85$  mmHg or on medication for hypertension; plasma triglyceride  $\geq 150$  mg/dl or on anti-cholesterol medications; plasma HDL-C  $\leq 50$  mg/dl (for females) or  $\leq 40$  mg/dl (for males); and fasting plasma glucose  $\geq 100$  mg/dl diagnosis of diabetes by a doctor.

Main independent variable: According to the questions in NHANES, participants who had never used marijuana/hashish were categorized as never marijuana users. Those who said they had used marijuana/hashish but not up to once a month for more than a year were classified as non-regular marijuana users and those who had used marijuana or hashish at least once a month for more than a year were classified as regular marijuana users.

We estimated years of marijuana use by subtracting each participant's age at regular marijuana use from their current age. For participants who were non-regular users of marijuana, we assigned zero years of marijuana use. Our multivariate logistic analysis included

only marijuana users (regular users or non-regular-users) to enable us assess the effect among those who had ever used marijuana and avoid placing non-regular marijuana users and never marijuana users on the same level.

| Variable                             | Diagnostic Criteria |       |         |       |
|--------------------------------------|---------------------|-------|---------|-------|
|                                      | WHO                 | EGIR  | ATP III | IDF   |
| <b>Metabolic Syndrome</b>            |                     |       |         |       |
| Overall                              | 9.21                | 8.55  | 23.17   | 23.37 |
| <b>BY SUBSTANCE USE (Yes)</b>        |                     |       |         |       |
| Regular marijuana                    | 8.40                | 8.40  | 20.93   | 21.3  |
| Current cigarette smoker             | 9.41                | 9.14  | 24.83   | 24.69 |
| <b>BY RACE (Yes)</b>                 |                     |       |         |       |
| NHW                                  | 9.43                | 9.97  | 24.71   | 22.01 |
| NHB                                  | 9.21                | 8.07  | 25.73   | 25.98 |
| MA                                   | 14.89               | 10.33 | 24.62   | 28.27 |
| OHISP                                | 7.83                | 5.69  | 21.71   | 25.27 |
| ASIANS                               | 5.39                | 6.79  | 15.46   | 18.03 |
| ORACE                                | 8.33                | 6.48  | 18.52   | 19.44 |
| <b>Hypertension</b>                  |                     |       |         |       |
| Overall                              | 10.56               | 23.89 | 31.69   | 31.69 |
| <b>Hyperglycemia</b>                 |                     |       |         |       |
| Overall                              | 19.04               | 8.19  | 21.86   | 23.43 |
| <b>Hyperinsulinemia</b>              |                     |       |         |       |
| Overall                              | 3.61                | 61.42 | -       | -     |
| <b>High OGTT Level</b>               |                     |       |         |       |
| Overall                              | 5.97                | 5.97  | -       | -     |
| <b>Hypertriglyceridemia</b>          |                     |       |         |       |
| Overall                              | 11.67               | 11.67 | 18.49   | 18.49 |
| <b>Low HDL-C</b>                     |                     |       |         |       |
| Overall                              | 10.49               | 15.34 | 34.81   | 34.81 |
| <b>High WC</b>                       |                     |       |         |       |
| Overall                              | -                   | 69.59 | 49.80   | 64.15 |
| NHW                                  | -                   | -     | -       | 50.07 |
| NHB                                  | -                   | -     | -       | 69.59 |
| ASIANS/MA/OHISP/OR                   | -                   | -     | -       | 74.57 |
| <b>BMI &gt;30 kg/m<sup>2</sup></b>   |                     |       |         |       |
| Overall                              | 35.59               | -     | -       | -     |
| <b>High Albumin/Creatinine Ratio</b> |                     |       |         |       |
| Overall                              | 13.27               | -     | -       | -     |

**Table 1b:** Prevalence in Percentages of Metabolic Syndrome Diagnosis and its Components by the Different Criteria.

NHW: Non-Hispanic Whites; NHB: Non-Hispanic Blacks; MA: Mexican Americans; OHISP: Other Hispanics; ORACE: Other Race or Multiracial; OGTT: Oral Glucose Tolerance Test; HDL-C: High Density Lipoprotein Cholesterol; WC: Waist Circumference; BMI: Body Mass Index.

Other independent variables: We included cigarette smoking. We classified participants who reported they have smoked at least 100 cigarettes their entire life and still smoke every day or some days as current cigarette smokers. Those who have smoked at least 100 cigarettes but do not currently smoke at all were past smokers. Those who had never smoked cigarettes were non-smokers. Non-smokers or past smokers were assigned zero years of smoking cigarettes. Years of smoking for current smokers was estimated by subtracting reported initial age at regular smoking from their current age.

In the multivariate model, we controlled for age of participant, gender, race, education, marital status, poverty to income ratio (PIR), participation in at least moderate physical activity, days of alcohol use in a week, other recreational substance use (methamphetamine, heroin or cocaine) and participation in rehabilitation. Details of the measurement of these control variables are described in NHANES manual.

### Statistical analysis

We used Stata/IC 14.0 software package for analysis. We estimated the proportions of demographic and clinical variables by race to have an appreciation of the differences. Disparities in socioeconomic factors as well as race/ethnicity have been described as important factors for metabolic abnormalities as well as recreational substance use [13,14]. Using logistic regression analysis, we estimated unadjusted and adjusted odds ratios for MetS among regular and non-regular marijuana users. In all analyses we applied the appropriate weights for the NHANES multi-stage survey design and used a two-tailed significance level of  $\alpha=0.05$  ([http://www.cdc.gov/nchs/data/nhanes/nhanes3/cdrom/NCHS/MANUALS/WGT\\_EXEC.PDF](http://www.cdc.gov/nchs/data/nhanes/nhanes3/cdrom/NCHS/MANUALS/WGT_EXEC.PDF)).

## Results

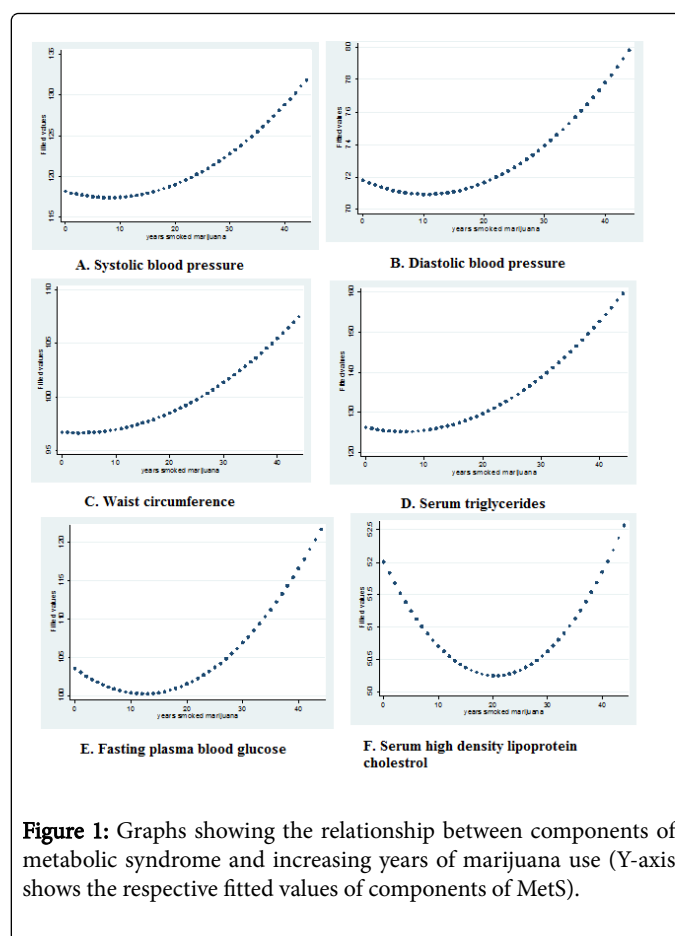
### Demographic and metabolic syndrome characteristics of study participants

Characteristics for the basic demographics and MetS with its components are shown in Tables 1a and 1b, respectively. Overall, 26.2% of participants were regular marijuana users and 24.0% were current cigarette smokers (Table 1a). Among the different racial/ethnic groups, people of other race/Multi-racials had the highest prevalence for marijuana use (40.7%) with Asians having the least (7.6%). Among all participants, the prevalence of other illicit drug use (cocaine, heroin or methamphetamine) was 17.7% whilst multiracial had the highest prevalence (28.7%). A higher proportion of Non-Hispanic Blacks (7.8%) have had rehabilitation compared to Multiracial (7.4%).

Of the four criteria, ATP III and IDF classify more people as having MetS (23.2% and 23.4%, respectively) and WHO criteria classify the least (9.2%) and EGIR (8.6%) (Table 1b). This pattern is also seen for MetS prevalence among marijuana users and cigarette smokers: the proportion of MetS among marijuana users was 21.3% (IDF) and

20.9% (ATP III) whilst the proportion of MetS among cigarette smokers was 26.0% (IDF) and 25.7% (ATP III). By race/ethnicity, ATP III classifies the 25.7% of non-Hispanic Blacks as having MetS. All other criteria predominantly classify Mexican Americans (MA) as having MetS (28.3%-IDF, 14.9%-WHO and 10.3%-EGIR).

Hypertension, hypertriglyceridemia, and Low HDL-C are more prevalent (31.7%, 18.5%, 34.8%, respectively) using ATP III and IDF criteria. The prevalence of hyperglycemia is 21.9% using ATP III and 23.4% using IDF. Disparities in prevalence for other components are shown in Table 1b.



**Figure 1:** Graphs showing the relationship between components of metabolic syndrome and increasing years of marijuana use (Y-axis shows the respective fitted values of components of MetS).

### Components of metabolic syndrome with years of marijuana use

The relationship between components of MetS and years of marijuana use are shown in Figure 1. Curvilinear relationships between years of marijuana use and components of MetS are apparent. The relationship of systolic blood pressure (SBP), diastolic blood pressure (DBP), waist circumference (WC), plasma triglycerides (TG)

and fasting blood glucose (FBG) with years of marijuana used tend to be J-shaped. This shows an initial decrease in values but eventual increase. The relationship between plasma high density lipoprotein cholesterol HDL-C and years of marijuana used was U-shaped. This shows an initial decrease and eventual increase.

### Bivariate analysis of metabolic syndrome and its components with years of marijuana use and cigarette smoking

By all the criteria, unadjusted analysis showed a universal increase in odds of having MetS with every year of marijuana use. With every year increase in marijuana use, the odds ratios (OR) for having MetS are 1.06 (95% CI: 1.03, 1.08) for ATP III, 1.06 (95% CI: 1.04, 1.08) for WHO, 1.05 (95% CI: 1.02, 1.08) for EGIR and 1.05 (95% CI: 1.03, 1.07) for IDF (Table 2a). By all applicable criteria, for each year of marijuana use, a significant increase in odds is observed for hypertension, hyperglycemia, high oral glucose tolerance test levels, hypertriglyceridemia, abdominal obesity and obesity.

The relationship with cigarette use shows increases in odds for MetS which is only significant by ATP III. For hypertension, hyperglycemia and high OGTT levels a significant increase in odds is demonstrated by all the criteria (Table 2b).

### Multivariate analysis

For every year of marijuana use, adjusted odds ratio (AOR) for having MetS (controlling for years of smoking, gender, age, marriage, education, country of birth, PIR, having health insurance, participating in at least moderate physical activity, weekly alcohol intake, other illicit drug use and undergoing rehabilitation) by ATP III and IDF criteria was 1.05 (95% CI: 1.02, 1.08). By WHO, AOR was 1.08 (95% CI: 1.04,

1.13) and by EGIR criteria, AOR was 1.06 (95% CI: 1.01, 1.11) (Table 3a).

Each year of marijuana use showed AORs for hypertension as: 1.07 (95% CI: 1.03, 1.12) by ATP III and IDF, 1.05 (95% CI: 1.01, 1.09) by WHO and 1.08 (95% CI: 1.03, 1.12) by EGIR All the applicable criteria show increased odds for abdominal obesity: 1.06 (95% CI: 1.00, 1.11) by ATP III, 1.09 (95% CI: 1.05, 1.14) by EGIR and 1.07 (95% CI: 1.01, 1.13) by IDF. For obesity the AOR was 1.03 (95% CI: 1.01, 1.06) according to WHO. The AOR for having a high oral glucose tolerance test level was 1.12 (95% CI: 1.07, 1.18) by WHO and EGIR.

Every year increase in smoking cigarette by this model, was associated with AOR of 1.05 (95% CI: 1.01, 1.09) for hypertension by WHO criteria. For abdominal obesity, the AOR was 0.97 (95% CI: 0.95, 0.99) by EGIR criteria (Table 3b).

### Discussion

Duration of marijuana use seems to be a significant factor associated with MetS. Its effect is small, but of the same order of magnitude or possibly greater than the effect of years of cigarette smoking. It must be noted that conventionally, cigarette smoking status has been used in analysis, but we attempted assessing the effect of years of smoking cigarette on MetS. Although current studies on marijuana use and MetS show a protective effect of marijuana on glycemic factors, this may be the result of not considering the years of using marijuana in cross sectional analysis. All criteria, demonstrate that every year increase in marijuana use is associated with at least 5% increase in odds of having MetS. In relation to components of MetS, a general increase in odds is observed with progress in years of using marijuana, however they vary by significance.

| Variable                    | Diagnostic Criteria     |                         |                         |                         |
|-----------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
|                             | ATP III                 | WHO                     | EGIR                    | IDF                     |
| <b>Metabolic Syndrome</b>   |                         |                         |                         |                         |
| Marijuana use <sup>1</sup>  | <b>1.06 (1.03-1.08)</b> | <b>1.06 (1.04-1.08)</b> | <b>1.05 (1.02-1.08)</b> | <b>1.05 (1.03-1.07)</b> |
| <b>Hypertension</b>         |                         |                         |                         |                         |
| Marijuana use <sup>1</sup>  | <b>1.06 (1.03-1.09)</b> | <b>1.09 (1.04-1.15)</b> | <b>1.08 (1.04-1.11)</b> | <b>1.06 (1.03-1.10)</b> |
| <b>Hyperglycemia</b>        |                         |                         |                         |                         |
| Marijuana use <sup>1</sup>  | <b>1.04 (1.00-1.08)</b> | <b>1.04 (1.00-1.09)</b> | <b>1.04 (1.00-1.08)</b> | <b>1.04 (1.00-1.08)</b> |
| <b>Hyperinsulinemia</b>     |                         |                         |                         |                         |
| Marijuana use <sup>1</sup>  | -                       | 1.03 (0.98-1.08)        | <b>1.04 (1.00-1.07)</b> | -                       |
| <b>High OGTT</b>            |                         |                         |                         |                         |
| Marijuana use <sup>1</sup>  | -                       | <b>1.07 (1.05-1.10)</b> | <b>1.07 (1.07-1.10)</b> | -                       |
| <b>Hypertriglyceridemia</b> |                         |                         |                         |                         |
| Marijuana use <sup>1</sup>  | <b>1.05 (1.03-1.07)</b> | <b>1.03 (1.01-1.06)</b> | <b>1.03 (1.01-1.08)</b> | <b>1.05 (1.03-1.07)</b> |
| <b>Low HDL-C</b>            |                         |                         |                         |                         |
| Marijuana use <sup>1</sup>  | <b>1.03 (1.00-1.06)</b> | 1.00 (0.97-1.03)        | <b>1.03 (1.00-1.05)</b> | <b>1.03 (1.00-1.06)</b> |
| <b>Abdominal Obesity</b>    |                         |                         |                         |                         |
|                             |                         | -                       |                         |                         |

|                                      |                         |                         |                         |                         |
|--------------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Marijuana use <sup>1</sup>           | <b>1.03 (1.00-1.07)</b> |                         | <b>1.07 (1.05-1.10)</b> | <b>1.03 (1.00-1.06)</b> |
| <b>Obesity</b>                       | -                       |                         | -                       | -                       |
| Marijuana use <sup>1</sup>           |                         | <b>1.03 (1.01-1.05)</b> |                         |                         |
| <b>High Albumin/Creatinine Ratio</b> | -                       |                         | -                       | -                       |
| Marijuana use <sup>1</sup>           |                         | 0.99 (0.96-1.02)        |                         |                         |

**Table 2a:** Unadjusted analysis of having metabolic syndrome and risky levels of components by the different criteria for each year of marijuana use, **bold** values indicate significance at  $\alpha < 0.05$ , Marijuana use<sup>1</sup> - each year of marijuana use among regular or non-regular marijuana users.

We observed different strengths in AORs for MetS with each year of marijuana use based on the different criteria for Mets, but the same direction of associations. Even though literature has discussed the possibility of a common definition for MetS [15-17], this suggests that the different criteria for metabolic syndrome may be comprehensive

and can produce unified relationships with respect to marijuana use. This is irrespective of the fact that WHO and EGIR set predefined risk factors on glucose or insulin impairment. However, WHO and EGIR criteria, showed marked reductions in prevalence. This is primarily due to the prequalifying criteria for glucose/insulin impairment.

| Variable                             | Diagnostic Criteria     |                         |                         |                         |
|--------------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
|                                      | ATP III                 | WHO                     | EGIR                    | IDF                     |
| <b>Metabolic Syndrome</b>            | <b>1.02 (1.01-1.05)</b> | 1.02 (0.98-1.05)        | 1.01 (0.99-1.04)        | 1.01 (0.99-1.03)        |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |
| <b>Hypertension</b>                  | <b>1.03 (1.00-1.06)</b> | <b>1.07 (1.03-1.12)</b> | <b>1.08 (1.04-1.11)</b> | <b>1.03 (1.00-1.06)</b> |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |
| <b>Hyperglycemia</b>                 | <b>1.02 (1.00-1.03)</b> | <b>1.02 (1.00-1.04)</b> | <b>1.04 (1.00-1.08)</b> | <b>1.02 (1.00-1.03)</b> |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |
| <b>Hyperinsulinemia</b>              | -                       | 1.03 (0.99-1.07)        | <b>1.04 (1.00-1.07)</b> | -                       |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |
| <b>High OGTT</b>                     | -                       | <b>1.02 (1.00-1.05)</b> | <b>1.07 (1.05-1.10)</b> | -                       |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |
| <b>Hypertriglyceridemia</b>          | <b>1.02 (1.01-1.04)</b> | <b>1.03 (1.00-1.05)</b> | <b>1.03 (1.01-1.06)</b> | <b>1.02 (1.01-1.04)</b> |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |
| <b>Low HDL-C</b>                     | 1.01 (0.99-1.02)        | 0.97 (0.94-1.01)        | <b>1.02 (1.00-1.05)</b> | 1.01 (0.99-1.02)        |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |
| <b>Abdominal Obesity</b>             | 1.00 (0.98-1.02)        | -                       | <b>1.07 (1.05-1.10)</b> | 1.00 (0.98-1.02)        |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |
| <b>Obesity</b>                       | -                       | 1.00 (0.98-1.02)        | -                       | -                       |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |
| <b>High Albumin/Creatinine Ratio</b> | -                       | 1.01 (0.99-1.03)        | -                       | -                       |
| Cig smoking <sup>1</sup>             |                         |                         |                         |                         |

**Table 2b:** Unadjusted analysis of having metabolic syndrome and risky levels of components by the different criteria for every year of cigarette smoking, **bold** values indicate significance at  $\alpha < 0.05$ , Cig smoking<sup>1</sup>-each year of cigarette use among regular or non-regular marijuana users.

Metabolic syndrome is a powerful tool for identifying people at risk for CVD and diabetes [15]. It is important that research on marijuana

demonstrate the true relationship with MetS and its components. These findings could provide a behavioral path to preventive and therapeutic interventions for CVD and diabetes [15] in relation to marijuana use.

Criteria of MetS is not settled, neither is the definition of marijuana use. Metabolic syndrome is a complex condition and there may be more factors intrinsic and extrinsic to MetS and marijuana use that need attention. This study finds that prolonged use of marijuana is a likely associated factor for MetS, glucose intolerance and hypertension. Increased years of marijuana use are also associated with hypertriglyceridemia but are significant using ATP III and IDF criteria. Even though all the criteria use a plasma triglyceride cut off  $\geq 150$  mg/dl, WHO and EGIR do not account for the use of cholesterol lowering medications and this could be a factor in the difference in significance. The recreational use of marijuana may ultimately threaten public health gains in the area of cardiovascular disease prevention. A longitudinal study of the relationship between recreational marijuana use and MetS concerning clinical factors and biological markers for all the four core attributes of MetS: insulin resistance, visceral obesity, atherogenic dyslipidemia and endothelial dysfunction [15] are exigent.

The active constituent of marijuana, delta-9-tetrahydrocannabinol (D-THC), acts on the endocannabinoid system (ECS), primarily CB1

receptors and CB2 receptors. The ECS plays a role in regulation of appetite and metabolism [18]. Modulation of the ECS affects the four core attributes of MetS [19]. These effects are being studied for management of obesity [20,21], dyslipidemia [21], atherosclerosis [22] and insulin resistance [20,23]. Cannabinoids or cannabis extracts may have therapeutic indications but, because absorption is erratic, the pharmacodynamics is still under active investigation for therapeutic purposes [24]. Arguments for recreational use of marijuana based on research for therapeutic use may need re-evaluation.

In Figure 1, initial reductions in blood pressure and glucose values change to increases after about five years of use. This shows a probable eventual deleterious effect on blood pressure and glycemic levels. However, after about twenty years of using marijuana, low levels of HDL-C tend to increase, which may allude an ultimate beneficial effect on HDL-C. This further stresses the complex relationship between cannabinoids and metabolic processes. All the applicable criteria show that increased years of marijuana use is associated with abdominal obesity. Active investigation of marijuana in long term metabolic derangements is important. Criteria by IDF show higher odds for abdominal obesity than ATP III. This is because IDF uses racial-ethnic specific waist circumference.

| Variable                       | ATP III                  | WHO                      | EGIR                     | IDF                       |
|--------------------------------|--------------------------|--------------------------|--------------------------|---------------------------|
| Marijuana use <sup>1</sup>     | <b>1.05 (1.02, 1.08)</b> | <b>1.08 (1.04, 1.13)</b> | <b>1.06 (1.01, 1.11)</b> | <b>1.05 (1.02, 1.08)</b>  |
| Cigarette smoking <sup>1</sup> | 1.01 (0.98, 1.04)        | 0.99 (0.95, 1.04)        | 1.00 (0.96, 1.04)        | 1.00 (0.97, 1.03)         |
| Age 25+                        | 2.70 (0.66, 11.10)       | 0.67 (0.12, 3.78)        | 0.92 (0.19, 4.45)        | 1.01 (0.37, 2.78)         |
| Males                          | 0.78 (0.29, 2.09)        | 2.54 (0.98, 6.63)        | 1.29 (0.45, 3.64)        | 0.71 (0.27, 1.90)         |
| Asians                         | 1.37 (0.18, 10.19)       | 1.72 (0.27, 10.82)       | 0.98 (0.19, 5.14)        | 1.41 (0.24, 8.19)         |
| Blacks                         | 0.74 (0.33, 1.66)        | 0.63 (0.13, 2.96)        | 0.59 (0.20, 5.08)        | 0.81 (0.36, 1.83)         |
| M Americans <sup>2</sup>       | 0.63 (0.22, 1.80)        | 1.54 (0.55, 4.27)        | 2.02 (0.96, 4.23)        | 1.16 (0.31, 4.28)         |
| Other Hispanics                | 0.22 (0.02, 2.55)        | 1.44 (0.33, 6.22)        | 1.01 (0.20, 5.08)        | 2.39 (0.40, 14.24)        |
| Other Race                     | 0.99 (0.22, 4.48)        | 0.89 (0.18, 4.46)        | 0.69 (0.20, 2.40)        | 1.45 (0.39, 5.47)         |
| Born in USA                    | 3.87 (0.44, 34.28)       | 3.04 (0.60, 15.29)       | 4.08 (0.84, 19.75)       | <b>5.53 (1.39, 22.08)</b> |
| Education                      | 0.97 (0.59, 1.59)        | 1.26 (0.94, 1.71)        | 1.39 (0.80, 2.40)        | 0.98 (0.61, 1.58)         |
| PIR <sup>3</sup>               | 0.93 (0.78, 1.10)        | 1.01 (0.65, 1.57)        | 0.91 (0.76, 1.09)        | 0.99 (0.81, 1.21)         |
| Insured                        | 1.25 (0.68, 2.27)        | 0.52 (0.25, 1.04)        | 0.66 (0.38, 1.15)        | 1.00 (0.52, 1.93)         |
| Married                        | 1.17 (0.53, 2.58)        | 0.83 (0.30, 2.33)        | 1.75 (0.63, 4.83)        | 1.78 (0.54, 2.58)         |
| Moderate PA <sup>4</sup>       | 1.17 (0.54, 2.51)        | 0.74 (0.31, 1.76)        | 0.85 (0.40, 1.79)        | 1.16 (0.53, 2.53)         |
| Alcohol Intake <sup>5</sup>    | <b>1.84 (1.10, 3.08)</b> | 0.74 (0.28, 1.99)        | 0.95 (0.52, 1.74)        | <b>1.69 (1.04, 2.74)</b>  |
| Other drug use                 | 0.92 (0.45, 1.89)        | 0.49 (0.21, 1.18)        | <b>0.39 (0.23, 0.64)</b> | 0.99 (0.46, 2.14)         |
| Rehabilitation                 | 1.01 (0.44, 2.33)        | 1.33 (0.50, 3.57)        | 1.66 (0.58, 4.77)        | 1.23 (0.55, 2.72)         |

**Table 3a:** Multivariate analysis of metabolic syndrome with years of marijuana use by different criteria controlling for cigarette smoking and other variables, 1-Each year increase in marijuana use or cigarette smoking; 2-Mexican American; 3-Family Income-to-Poverty Ratio; 4-At least moderate physical activity (recreational); 5-Weekly, **bold** values indicates significant at  $\alpha < 0.05$ ; ATP III-National Cholesterol Examination Panel, Adult Treatment Panel III; EGIR: European Group for the Study of Insulin Resistance; IDF: International Diabetes Federation; WHO: World Health Organization.



In this study, non-significant varying relationships are observed with each year of cigarette smoking and the different criteria for MetS. This relationship could be explained by the combination of non-smokers and past smokers. For marijuana use, all participants had at least used marijuana before. The association of cigarette smoking status with hypertension is established knowledge [25,26]. Increased years of cigarette smoking was also associated with increased odds for high OGTT levels (WHO and EGIR). Research has shown that diabetic patients who continue to smoke have uncontrolled glucose levels even with treatment [27]. Studies have long shown that nicotine from cigarette smoking impairs glucose metabolism [28-30] and reflects as high proportions of glycated hemoglobin, high OGTT and high fasting insulin [31,32].

### Strengths and limitations

Demographic, lifestyle, clinical, laboratory parameters and a large nationally representative sample was obtained from NHANES data, however this cross-sectional study estimates associations not risks. Marijuana use was self-reported and the study may have a reporting bias especially with information on illicit substance use as marijuana. We initially controlled for the quantity of marijuana used but this did not significantly affect the results and was excluded from the model.

|   | ATP III                  | WHO                      | EGIR                     | IDF                      |
|---|--------------------------|--------------------------|--------------------------|--------------------------|
| <b>Hypertension</b>                           |                          |                          |                          |                          |
| Marijuana use <sup>1</sup>                    | <b>1.07 (1.03, 1.12)</b> | <b>1.05 (1.01, 1.09)</b> | <b>1.08 (1.03, 1.12)</b> | <b>1.07 (1.03, 1.12)</b> |
| Cigarette smoking <sup>1</sup>                | 1.02 (0.98, 1.05)        | <b>1.05 (1.02, 1.09)</b> | 1.02 (0.99, 1.05)        | 1.02 (0.98, 1.05)        |
| <b>Hyperglycemia</b>                          |                          |                          |                          |                          |
| Marijuana use <sup>1</sup>                    | 1.02 (0.98, 1.07)        | 1.02 (0.98, 1.07)        | 1.02 (0.98, 1.07)        | 1.02 (0.98, 1.07)        |
| Cigarette smoking <sup>1</sup>                | 1.00 (0.97, 1.03)        | 1.00 (0.97, 1.03)        | 1.00 (0.97, 1.03)        | 1.00 (0.97, 1.03)        |
| <b>Hyperinsulinemia</b>                       |                          |                          |                          |                          |
| Marijuana use <sup>1</sup>                    | -                        | 1.01 (0.92, 1.11)        | 1.04 (0.99, 1.11)        | -                        |
| Cigarette smoking <sup>1</sup>                | -                        | 1.00 (0.97, 1.03)        | 1.00 (0.96, 1.04)        | -                        |
| <b>High Oral Glucose Tolerance Test level</b> |                          |                          |                          |                          |
| Marijuana use <sup>1</sup>                    | -                        | <b>1.12 (1.07, 1.18)</b> | <b>1.12 (1.07, 1.18)</b> | -                        |
| Cigarette smoking <sup>1</sup>                | -                        | 0.99 (0.96, 1.03)        | 0.99 (0.96, 1.03)        | -                        |
| <b>Hypertriglyceridemia</b>                   |                          |                          |                          |                          |
| Marijuana use <sup>1</sup>                    | <b>1.04 (1.00, 1.07)</b> | 1.02 (0.98, 1.05)        | 1.02 (0.98, 1.05)        | <b>1.04 (1.00, 1.07)</b> |
| Cigarette smoking <sup>1</sup>                | 1.01 (0.99, 1.03)        | 1.01 (0.98, 1.05)        | 1.01 (0.98, 1.05)        | 1.01 (0.99, 1.03)        |
| <b>Low HDL-C</b>                              |                          |                          |                          |                          |
| Marijuana use <sup>1</sup>                    | 1.03 (0.99, 1.07)        | 1.02 (0.98, 1.07)        | 1.04 (0.99, 1.08)        | 1.03 (0.99, 1.07)        |
| Cigarette smoking <sup>1</sup>                | 0.99 (0.97, 1.02)        | 0.97 (0.92, 1.02)        | 0.98 (0.93, 1.03)        | 0.99 (0.97, 1.02)        |
| <b>Abdominal obesity</b>                      |                          |                          |                          |                          |
| Marijuana use <sup>1</sup>                    | <b>1.06 (1.00, 1.11)</b> | -                        | <b>1.09 (1.05, 1.14)</b> | <b>1.07 (1.01, 1.13)</b> |
| Cigarette smoking <sup>1</sup>                | 0.99 (0.97, 1.02)        | -                        | <b>0.97 (0.95, 0.99)</b> | 0.95 (0.95, 1.01)        |
| <b>Obesity by (BMI)</b>                       |                          |                          |                          |                          |
| Marijuana use <sup>1</sup>                    | -                        | <b>1.03 (1.01, 1.06)</b> | -                        | -                        |
| Cigarette smoking <sup>1</sup>                | -                        | 0.99 (0.97, 1.01)        | -                        | -                        |
| <b>High Albumin/ Creatinine ratio</b>         |                          |                          |                          |                          |
| Marijuana use <sup>1</sup>                    | -                        | 0.96 (0.91, 1.01)        | -                        | -                        |
| Cigarette smoking <sup>1</sup>                | -                        | 1.01 (0.97, 1.05)        | -                        | -                        |

**Table 3b:** Multivariate analysis of components of metabolic syndrome with each year of marijuana use and cigarette smoking by different criteria

We did not control for diet, an important factor for MetS, however, we controlled for factors important in dietary and health decisions as income to poverty ratio (PIR), alcohol use, physical activity, health insurance and education. For ethnic-specific waist circumference by IDE, we classified NHBs as Europids based on ancestral genesis [33] that the ancestry of Blacks or African-American are predominantly Niger-Kordofanian (~71%), European (~13%) or other African (~8%) populations [34]. All NHBs were classified using values for Americans since distinctions based on the ethnic classification were unavailable. We however controlled for place of birth to possibly account for these differences.

## Conclusion

Irrespective of the criteria for metabolic syndrome, each year of marijuana use showed increased odds of having metabolic syndrome, hypertension or high oral glucose tolerance test levels. Extended duration of marijuana use could possibly increase the risk for the development of metabolic syndrome. Longitudinal studies can show this risk. Irrespective of the criteria for MetS, we estimated increased odds of MetS with each year marijuana use. This may constitute an important pathway between marijuana use and cardiovascular disease in later life. The impact of duration of marijuana use should be considered in assessing the relationships with MetS.

Longitudinal research is required to define the true relationship between marijuana use and metabolic syndrome. If a cardiovascular risk is established, a good understanding of the pathogenesis of metabolic syndrome and metabolic pathways of marijuana metabolites should be laid out. This will help address any risk factors which may initiate and facilitate CVD progression among marijuana users.

## Conflict of Interest

We declare no conflict of interest in processes associated with this study. All authors contributed equally in the research. Grants or Financial Support: The authors received no financial support for the study.

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