The Impact of Legalized Recreational Marijuana Laws on Obesity

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Abstract

This study investigates the causal effect of recreational marijuana laws (RMLs) on body mass index (BMI) using data from the CDC's Behavioral Risk Factor Surveillance System (BRFSS). While numerous studies have explored the association between marijuana use and appetite, few have examined the causal evidence between marijuana use and BMI. Leveraging the staggered adoption of RMLs as a natural experiment, we employ a Two-Stage Difference-in-Difference (2SDiD) model to estimate the effect of RMLs on BMI. Although our initial 2SDiD point estimates indicate a significant decrease in BMI of approximately 0.294 units or 1.08 percent (0.294/27.33), the event-study analysis reveals a downward pre-trend in BMI prior to the implementation of RMLs. After accounting for this pre-trend, our findings suggest that RMLs have no statistically significant effect on BMI. Moreover, we find little evidence for potential mechanisms, or for heterogeneous effects depending on gender and age groups.

Keywords: Recreational Marijuana Laws (RMLs), Body Mass Index (BMI), Obesity
JEL Codes: I12, I18, K23, K32

1 Introduction

Over the past two decades, obesity has increased from 30.5% to 41.9% in the U.S. (Centers for Disease Control and Prevention, 2024). As obesity is a significant burden on public health and human resources (Cawley et al., 2021; Tzenios, 2023), it has been studied extensively (Safaei et al., 2021; Tremmel et al., 2017). The rising prevalence of obesity induces higher social costs, increasing the rate of preventable diseases and death (Bhaskaran et al., 2014; Dixon, 2010). The estimated annual medical cost is higher for obese individuals compared to normal-weight individuals (Cawley and Meyerhoefer, 2012; Cawley et al., 2021).

As of 2023, 24 states in the U.S. have passed Recreational Marijuana Laws (RMLs), leading to a substantial increase in the accessibility of marijuana (Cerda et al., 2017; Clarke et al., 2018; Paschall and Grube, 2020). National Center for Drug Abuse Statistics (2023) indicates that 16.9% of American adults are active marijuana users, and 45% have tried marijuana consumption at least once. Given the growing popularity of marijuana use, extensive medical studies have examined the potential health implications (Lotan et al., 2014; National Academies of Sciences et al., 2017; Volkow et al., 2016; Vu et al., 2014). Recreational marijuana users are more strongly associated with cigarette and substance use as compared to medical marijuana use (Cerdá et al., 2020; Coley et al., 2021; Chiu et al., 2021; Freisthler et al., 2017).

Beyond the spillover effects of substance use, there exists a potential association between marijuana use and Body Mass Index (BMI) (Rodondi et al., 2006; Sansone and Sansone, 2014; Smit and Crespo, 2001; Warren et al., 2005). There is some evidence to suggest that marijuana use may induce weight loss due to metabolic effects (Clark et al., 2018; Le Foll et al., 2013). In contrast, Foltin et al. (1986, 1988) find evidence that marijuana use is associated with increased calorie intake. More recent studies also find that marijuana use stimulates appetite (Berry and Mechoulam, 2002; Foltin et al., 1986; Kirkham, 2009; Soria-Gómez et al., 2014) and influences a consumer's consumption patterns by increasing food expenditures (Baggio et al., 2020; Hodge and Hazel, 2022; Lu, 2021).

According to the 'calories in, calories out' paradigm (Howell and Kones, 2017), increased appetite and rising food expenditures may lead to higher calorie intake, while reduced physical activity decreases calorie expenditure, potentially resulting in weight gain. However, marijuana use may also lead to a decrease in calorie intake, e.g. substituting marijuana use for alcohol consumption (Crost and Guerrero, 2012; Mark Anderson et al., 2013), which could offset the increase in appetite and reduce overall caloric intake, potentially mitigating weight gain. There could be endogeneity concerns regarding marijuana use and body weight (Le Strat and Le Foll, 2011; Rodondi et al., 2006; Sansone and Sansone, 2014). For example, obese individuals might tend to use marijuana more frequently, or marijuana users may be likely to neglect their health (Dare et al., 2015; Gümüş et al., 2013).

To address some of these concerns in a quasiexperimental framework, Sabia et al. (2017) employed the passage of medical marijuana laws (MMLs) as an exogenous variation, finding that MMLs are associated with a 0.6% reduction in BMI, observed during the post-implementation period five years later. We note the significant long-term gap between the implementation of MMLs and RMLs.[1] Furthermore, given the limited legal accessibility of marijuana in MML states (Mark Anderson et al., 2013; Pacula et al., 2015; Sarvet et al., 2018), examining changes in the obesity rate under RMLs, where access should increase, is a logical next step.[2] March et al. (2022) leveraged the enactment of RMLs and found a decrease in the obesity rate in the case of Washington state, but the extent to which these findings may be more broadly applied is unclear.[3]

We first approach the impact of RMLs on marijuana consumption by utilizing data from the National Survey on Drug Use and Health (NSDUH). For data on BMI, we use the Centers for Disease Control and Prevention's (CDC) Behavioral Risk Factor Surveillance

[1]By 2023, a total of 24 states had enacted RMLs following the implementation of MMLs. Only five states adopted RMLs within five years of implementing MMLs: District of Columbia, Massachusetts, Missouri, Virginia, and Washington.

[2]We control for the impact of MMLs in our analysis. Our estimate demonstrates a greater magnitude as RMLs further expand accessibility to marijuana use (Sabia et al., 2017).

[3]Lu (2021) examined the effect of RMLs on households' spending on food and alcohol, finding that RMLs increase spending on alcohol and food consumed away from home. This would seem to run counter to the findings in March et al. (2022).

System (BRFSS). We employ a Two-Way Fixed Effect (TWFE) model, comparing states that enact RMLs and those that do not, to estimate the average treatment effect of the policy. However, the staggered adoption of RMLs may generate biased estimates (Callaway and Sant'Anna, 2021; Goodman-Bacon, 2021), so we employ an alternate method, Two-Stage Difference-in-Differences (2SDiD), to account for the staggered adoption of the policy (Gardner, 2022). In addition, we examine heterogeneity by sex and age group,[4] as well as potential mechanisms for weight loss.

Overall, we find that the passage of RMLs leads to an increase in marijuana consumption of 5.1 percentage points, implying that RMLs expand the accessibility of marijuana use. Initial estimates show that RML decreases BMI by 0.84% (0.230/27.33) in the TWFE model, while 2SDiD indicates that there is a reduction in BMI of 1.08% (0.294/27.33). However, our finding also shows evidence of a linear decreasing trend in the pre-implementation period. We subsequently adjust our estimates by de-trending based on pre-period values, after which we find no statistically significant impact of RMLs on BMI. Although Sabia et al. (2017) and March et al. (2022) provide suggestive evidence that RMLs would potentially decrease body weight, we do not find evidence supporting this conclusion.

2 Background

Table 1 presents the effective dates for MMLs, RMLs, and the permitting of retail recreational sales. Since the first MML was passed in California in 1996, the use of medical marijuana has been approved in 36 states as well as the District of Columbia as of 2023.[5] However, marijuana for medical use can only be obtained from state-licensed dispensaries, which are limited in number (Anderson et al., 2014; Pacula et al., 2015).

Following considerable debate by policymakers (Hall and Lynskey, 2009; McGinty et al.,

[4] Following results from Sabia et al. (2017).

[5] In 1996, California voters approved the Compassionate Use Act (Reinarman et al., 2011). The act allowed patients to possess and use cannabis for medical purposes with the permission of a physician (Anderson and Rees, 2023; Nussbaum et al., 2011).

2017), several states that passed MMLs have also legalized recreational marijuana use. RMLs do not require a prescription or registration with state authorities, and anyone living in the state and at least 21 years old is eligible to purchase recreational marijuana from recreational dispensaries (Anderson and Rees, 2023; Dave et al., 2023). Colorado and Washington passed RMLs in 2012 (Cerda et al., 2017; Payan et al., 2021); as of 2023, 24 states have done so.

Column (1) of Table 1, presents the year and month when the MMLs were passed. While 13 states, including Alabama, Georgia, Indiana, Iowa, Kansas, Kentucky, North Carolina, South Carolina, South Dakota, Tennessee, Texas, Wisconsin, and Wyoming, have not passed MMLs, they have legalized the use of Cannabidiol (CBD), extracted ingredients from marijuana (Alharbi, 2020). Columns (2) and (3) specify the year and month of the enactment of RMLs and the opening date of the first dispensary, respectively. Importantly, the dates of RMLs are not aligned with the first recreational dispensary openings. RMLs and first dispensaries openings are controversial topics in measuring policy effects (Anderson and Rees, 2023; Pacula et al., 2015). Although the opening date of recreational marijuana stores might increase access to marijuana, the expansion rate and number of stores vary by state (Anderson and Rees, 2023). Furthermore, changes in marijuana consumption may not directly align with the opening of legal dispensary stores, as access may increase from other sources after legal penalties are reduced or removed.[6]

3 Data

We use the 2002-2018 NSDUH data to examine the effect of RMLs on marijuana consumption among individuals aged 12 or older by state. The NSDUH is a nationally representative survey administered by the Substance Abuse and Mental Health Services Administration (SAMHSA). Wen et al. (2015) utilizes the NSDUH data in finding that MMLs increase marijuana use among adults by 14% on average.

[6]We use the effective date of RMLs in our analysis, controlling for MMLs and the opening dates of legal dispensary stores.

To examine the effect of RMLs on BMI, we use the CDC BRFSS, a repeated cross-sectional nationally representative survey, from 1996-2022.[7] The survey is conducted through telephone via landline prior to 2010, and landline and cellular phone after 2011. The BRFSS includes health outcomes and health behaviors with a large sample size.

Our primary outcome variable is BMI, measured by the respondent's self-reported weight and height.[8] Table 2 presents weighted means and standard deviations for variables used in the analysis. For the full sample, the average BMI is 27.33, which falls within the overweight range. We further dichotomize the BMI variable into two categories, overweight and obese, based on BMI. Overweight is an indicator variable which includes individuals with a BMI of 25 or higher. Approximately 62% of the sample falls within the overweight range. Obese represents those with a BMI of 30 or higher. Around 26% of the sample are classified as obese. We include age, sex, race, and educational level as demographic control variables. Finally, we also control for state-level factors, including cigarette taxes, alcohol taxes, unemployment rates, and minimum wage levels.

4 Empirical Methodology

RMLs are not implemented uniformly in time across treated states, but rather are adopted in a staggered fashion. This can lead to a variety of issues in the estimation of a potential causal effect (Goodman-Bacon, 2021; Roth et al., 2023; Baker et al., 2022). Consequently, we employ two approaches: a standard TWFE model in equation (1), and a 2SDiD model designed to account for issues of staggered adoption, in equation (2) (Gardner, 2022).

[7] Although we can estimate the first-stage result using NSDUH, we can not distinguish between medical and recreational users in BRFSS. However, previous studies have also employed the BRFSS to examine the legalized marijuana laws on health behaviors (Choi et al., 2019; Mark Anderson et al., 2013; Sabia et al., 2017).

[8] Although the BMI used in the study is self-reported, the measurement error should not result in a biased estimate unless the measurement error is associated with the legalized RMLs (Sabia et al., 2017). The formula used in BMI is $(\text{weight(lb)}/[\text{height(in)}]^2) * 703$ and we excluded respondents whose BMI measure was below 10 and above 50 from our analysis sample.

4.1 Two-Way Fixed Effects (TWFE)

Following Mark Anderson et al. (2013) and Sabia et al. (2017), we estimate the TWFE model:

$$\text{BMI}_{i,s,t} = \alpha + \beta_1 \text{RML}_{s,t} + \beta_2 \boldsymbol{X_{i,s,t}} + \gamma_s + \delta_t + \varepsilon_{i,s,t} \tag{1}$$

Outcomes refer to individual i in state s during year t. The terms γ_s and δ_t are state and year fixed effects, respectively. $\boldsymbol{X_{i,s,t}}$ includes age, sex, race, and education. Weights employed are BRFSS sample weights.

4.2 Two-Stage Difference-in-Difference (2SDiD)

To account for heterogeneous treatment effects over time, we implement the 2SDiD model, as specified in equations (2) and (3):

$$\text{BMI}_{i,s,t} = \gamma_s + \delta_t + \beta_2 \boldsymbol{X_{i,s,t}} + \nu_{i,s,t} \tag{2}$$

$$\text{BMI}_{i,s,t} - \hat{\gamma}_s - \hat{\delta}_t - \widehat{\beta}_2 \boldsymbol{X_{i,s,t}} = \alpha + \beta_1 \text{RML}_{s,t} + \varepsilon_{i,s,t} \tag{3}$$

The model begins with a first stage on the untreated units, which is designed to impute a regression estimate for comparison with treated units by regressing in the second stage using the residuals from the first. In Equation (3), $\hat{\gamma}_s$, $\hat{\delta}_t$, $\widehat{\beta}_2$ are estimated in the first-stage regression. This procedure provides an efficient estimate of the potential heterogeneous treatment effects across groups, even in the presence of a staggered treatment timing (Gardner, 2022).

4.3 Threats to Identification

The primary threat to identification is the requirement of parallel trends in treated and control groups. We address this concern by examining event studies using both the TWFE and 2SDiD models. As BRFSS is conducted at the year level, we consider five years of lead and lag coefficients in the event study designs.

Another concern is the staggered adoption of RML policies, in two respects. First, MMLs, while qualitatively different from RMLs, are nonetheless present in some states for several years prior to RML adoption. We contend that the actual implications of MML in a state are different enough from RML that their effects may be accounted for in terms of state fixed effects; moreover, many MML states take months or even years to allow for legal dispensaries to open in limited geographic areas (Pacula et al., 2015). Second, staggered adoption of RMLs can yield estimates contaminated by negative weighting in the standard TWFE model (Goodman-Bacon, 2021; Wing et al., 2024). We account for this issue by using the 2SDiD estimator (Gardner, 2022). This regression imputation approach allows us greater flexibility in the staggered design, and also gives us a point of comparison for the standard estimator.

4.4 Pre-Trend Adjustment Procedure

Upon running our models, we found that multiple lead coefficients in the BMI event studies appear to be significantly different from zero (i.e. the confidence intervals do not overlap zero). Moreover, we see what appears to be a declining trend in BMI during the pre-period as the state gets closer in time to RML passage. As a result, despite statistically significant values for the treatment effect in the post-period, we are concerned that this may simply reflect existing trends in BMI at the state level.

To address this, we use a method to account for the trend.[9] We begin by assigning

[9]We attribute this method of accounting for pre-period trends to Andrew Goodman-Bacon, based on an email exchange with Michael F. Pesko concerning this issue in difference-in-differences empirical applications.

placebo treatment dates to control states. Then, we estimate unit-specific trends using only pre-period data. From these, we generate residuals and then run our event study specification using the residuals as the dependent variable. The effect of this process is to de-trend using only the pre-period, leaving any potential trends due to treatment effect in the post-period intact.

5 Results

5.1 Main Results

Table 3 presents the effect of RMLs on marijuana consumption. Columns (1) and (2) display the TWFE model, and Columns (3) and (4) show 2SDiD estimates. TWFE estimates indicate that RMLs raise marijuana consumption by 3.836 percentage points, which can be interpreted as a 30.83% (3.836/12.44) increase in response to RMLs. 2SDiD estimates in Column (4) indicate that RMLs lead to 5.107 percentage points or 41.04% (5.107/12.44) increase.

Figure 1 presents event study estimates of the effect of RMLs on marijuana consumption, using TWFE and 2SDiD, respectively. The reference point is defined as year 0, corresponding to the normalized year of RML passage in treated states. Prior to the enactment of RMLs, the TWFE model (left) shows a slight upward trend in marijuana consumption, followed by a sharp increase immediately after the policy's implementation, and then a subsequent decline. However, in the 2SDiD accounting for staggered adoption (right) marijuana consumption demonstrates an increasing trend following the RMLs. Overall, RMLs lead to an increase in average marijuana consumption. Our findings indicate a higher increase in the rate of marijuana use compared to the impact of only MMLs as reported in previous studies (Chu, 2014; Wen et al., 2015).

Table 4 reports the estimated impact of RMLs on BMI and on BMI classification indicators for overweight and obesity. In Panel A, the unadjusted TWFE estimate (Column 1) indicates that RMLs are associated with a 0.82% (0.224/27.33) decline in average BMI, while the unadjusted 2SDiD estimate (Column 3) suggests a 1.06% (0.289/27.33) decline. After accounting for pre-existing trends (Columns (2) and (4)) the estimated effects are reduced to a 0.27% (0.074/27.33) decline in BMI in the TWFE model and a 0.35% (0.097/27.33) decline in the 2SDiD model, only the former of which is statistically significant. The event studies in Figure 2, however, indicate a null effect from the policy; only coefficients outside the range of the event study show a negative effect (over 5 years post-RML implementation).

Panels B and C report the effects on the overweight and obese indicators, respectively. In the unadjusted 2SDiD specification (Panel B and C, Column 3), RMLs are associated with a 1.59% (0.010/0.629) decline for the overweight indicator, and a 6.42% (0.017/0.265) reduction for the obese indicator. However, after pre-trend adjustment (Panels B and C, Column 4), these effects are no longer statistically significant.

In Figure 2, we present event study estimates for the effect of RMLs on BMI using TWFE and 2SDiD, respectively. The figures display the TWFE model in row (a) and the 2SDiD model in row (b), unadjusted model on the left, and pre-trend adjusted model on the right. In the unadjusted models, there is a noticeable downward trend in BMI following the enactment of RMLs, particularly in the 2SDiD specification, where the reduction appears more pronounced over time. However, once we adjust for pre-existing trends, the post-treatment trajectory becomes essentially flat, suggesting that the observed declines may simply reflect ongoing trends rather than a causal impact of RMLs.

Figures 3 and 4 reveal a similar story for the overweight and obese populations, respectively. Initially, the event study results indicate statistically significant declines in the likelihood of being overweight or obese after RML enactment. Yet, following pre-trend adjustment, these effects are substantially diminished and lose statistical significance. Collectively, these findings highlight that the apparent improvements in BMI-related outcomes post-RML may be driven by pre-policy trends rather than the policy itself.

5.2 Subgroup Analysis: Sex and Age Groups

Panels A, B, and C of Table 5 in Columns (1) and (2) present the effect of RMLs on BMI, the likelihood of being overweight, and the likelihood of being obese by sex using 2SDiD. In Panel A, the 2SDiD results indicate that RMLs are associated with a statistically significant decline in BMI for both males and females, a 0.80% (0.221/27.67) decline for males, and a 1.37% (0.370/26.97) decline for females. However, once we adjust for pre-policy trends, the negative effects are considerably attenuated for both genders, reducing the observed heterogeneity.[10]

Panels B and C extend the analysis to the overweight and obesity indices. The unadjusted estimates suggest modest declines in the probability of being overweight and larger reductions in the probability of being obese across both gender groups. Yet, as with BMI, pre-trend adjustment diminishes these effects to the point that they are no longer statistically significant, except for the probability of being obese for males, which indicates that RMLs are associated with a 3.01% (0.008/0.266) decline.

Columns (3) to (7) present the effect of RMLs on BMI, the likelihood of being overweight, and the likelihood of being obese by age group. In Panel A, the unadjusted results reveal that middle-aged populations (e.g., 40-49, and 50-59 years) exhibit more pronounced reduction in BMI following the enactment of RMLs compared to other age groups. Specifically, the passage of RMLs is associated with a 1.61% (0.450/27.87) decline for the 40- to 49-year-old age group and a 1.28% (0.360/28.26) decline for the 50- to 59-year-old age group. The statistical significance still holds after correcting for the pre-trends, however, the effects are diminished to a 0.7% (0.195/27.87) decline for the 40- to 49-year-old age group and a 0.52%(0.148/28.26) decline for the 50- to 59-year-old age group. Regarding the probability of being overweight and obese (Panel B and C), the unadjusted results show that middle-aged groups (e.g., 40-49 and 50-59 years) tend to exhibit larger reductions following RMLs enactment compared to younger cohorts. However, after correcting for pre-trends, the differences

[10]See Figure 5 for a graphical presentation of the coefficients.

across age groups largely vanish, suggesting that the initial heterogeneity may be driven by pre-existing trends rather than a direct causal effect of RMLs. Overall, Table 5 highlights that although the initial (unadjusted) estimates imply some variation in the impact of RMLs on BMI and its classification by sex and age, these differences largely disappear when accounting for pre-policy trends. This finding is consistent with our full sample results.

5.3 Mechanisms

Although our trend-adjusted event studies suggest no statistically significant effect from RML passage on BMI, we investigate potential mechanisms for clarification. Generally, we would expect a reduction in body weight either from reduced calorie intake, increased physical activity, or a combination of the two. To investigate these options, we examine three outcomes using the BRFSS: an indicator for vigorous physical activity, the number of alcoholic drinks consumed per year, and the incidence of binge drinking. The results in Table 6 show a fairly precise zero for vigorous activity and insignificant but negatively signed values for binge drinking. Interestingly, we observe significant negative effects on the number of alcoholic drinks consumed across all our specifications.[11]

The primary estimate shows a 10.8 drink reduction from a mean of 146, or about 7.4%. If we assume that each drink is reflective of one standard drink (i.e. 0.6 fl. oz ethanol), we could assume this reduction takes the form of, for example, ten beers. This would be approximately 300 calories per beer, or 3000 calories total. This is approximately the same number of calories required to lose about 0.5kg of body mass, which is on the order of the 1% decline in BMI we observe in our analysis. Is this a plausible story, given that it is derived from self-reported drinking? To clarify, we turn to another data source, the Bureau of Labor Statistics Consumer Expenditure (CE) survey. We use the CE interview survey data covering 1996-2023, showing spending at the quarterly level by household. Spending is

[11] Although we note that the BRFSS alcohol consumption variable is not entirely reliable due to missing data, these results are suggestive. There are mixed results regarding the impact of MMLs on alcohol consumption (Veligati et al., 2020; Wen et al., 2015). See also Alley et al. (2020); Dragone et al. (2019) and Miller and Seo (2021).

inflation-adjusted to 2023 dollar values. Results are presented in Table 7. In contrast to the BRFSS data, we show an increase in spending (not statistically significant) on alcohol, both for consumption at home and away from home. Moreover, we find positively signed estimates for food purchases for consumption at home and away from home.[12] The confidence intervals for the at-home purchases do not overlap zero. Certainly spending is not a perfect proxy for consumption, but we might expect negatively signed coefficients on alcohol spending in the CE data if consumption were actually decreasing. That we find the opposite casts doubt on the validity of the BRFSS drinking results. The positively signed coefficients on food also do not indicate a decline in consumption.[13]

6 Conclusion

Given the high and increasing incidence of obesity in the population, evidence of any beneficial effect from the relaxation of drug laws would be welcome news to policymakers. Prior evidence from Sabia et al. (2017) and March et al. (2022) suggests that RMLs may lead to a decrease in BMI. Our empirical results indicate that RMLs do increase the probability of marijuana consumption by around 5.1 percentage points on average. However, we find that RML-adopting states show a declining trend in BMI for several years prior to RML passage, relative to non-adopting states. The continuation of this trend into the post-period can lead to the appearance of a decline in BMI when using difference-in-differences models, but this is unsupported after we account for this pre-trend in our analysis. Some potentially statistically significant effects among middle-aged individuals and males are small in magnitude (less than 1% of the mean BMI) and unconvincing given the lack of effects on the overweight and obese indicators.

Apart from BMI itself, we investigate potential mechanisms for weight loss or gain that

[12] Wilk et al. (2024) shows an increase in junk food spending following RML passage, along with a decrease in exercise.

[13] We also examined several small categories of spending using the CE diary survey data, which offers more precise food types. Here, we observed a significant ($p < 0.05$) positive effect on snack spending of about 11%. Other coefficients on similar categories were positive using our preferred specification.

could be affected, including exercise, alcohol use, and food and alcohol purchasing behavior. Since individuals may respond in a variety of ways to increased access to marijuana, potentially engaging in both substitution from alcohol to marijuana (a decrease in calorie intake) and increasing food consumption in a complementary fashion (an increase in calorie intake), the theoretical mechanism is itself ambiguous. Empirically, we fail to find convincing evidence of mechanisms that could lead to weight loss. Coupled with the lack of evidence for a decrease in BMI, we conclude that RMLs do not lead to overall weight loss at the population level.

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A Tables

Table 1: Effective Dates for Medical and Recreational Marijuana Legalization

	(1) MML effective dates	(2) RML effective dates	(3) Retail recreational sales allowed
Arkansas	Nov. 2016		
Alaska	Mar. 1999	Feb. 2015	Oct. 2016
Arizona	Apr. 2011	Nov. 2020	Jan. 2021
California	Nov. 1996	Nov. 2016	Jan. 2018
Colorado	Jun. 2001	Dec. 2012	Jan. 2014
Connecticut	May. 2012	Jul. 2021	Jan. 2023
Delaware	Jul. 2011	Apr. 2023	
District of Columbia	Jul. 2010	Feb. 2015	Feb. 2015
Florida	Jan. 2017		
Hawaii	Dec. 2000		
Illinois	Jan. 2014	Jan. 2020	Jan. 2020
Louisiana	May. 2016		
Maine	Dec. 1999	Jan. 2017	Oct. 2020
Maryland	Jun. 2014	May. 2023	Jul. 2023
Massachusetts	Jan. 2013	Dec. 2016	Nov. 2018
Michigan	Dec. 2008	Dec. 2018	Dec. 2019
Minnesota	May. 2014	Aug. 2023	
Mississippi	Feb. 2022		
Missouri	Nov. 2018	Dec. 2022	Feb. 2023
Montana	Nov. 2004	Jan. 2021	Jan. 2022
Nevada	Oct. 2001	Jan. 2017	Jul. 2017
New Hampshire	Jul. 2013		
New Jersey	Oct. 2010	Feb. 2021	Apr. 2022
New Mexico	Jul. 2007	Jun. 2021	Apr. 2022
New York	Jul. 2014	Mar. 2021	Dec. 2022
North Dakota	Dec. 2016		
Ohio	Sep. 2016		
Oklahoma	Jun. 2018		
Oregon	Dec. 1998	Jul. 2015	Oct. 2015
Pennsylvania	May. 2016		
Rhode Island	Jan. 2006	May 2022	Dec. 2022
Utah	Dec. 2018		
Vermont	Jul. 2004	Jul. 2018	Oct. 2022
Virginia	Jul. 2020	Jul. 2021	
Washington	Nov. 1998	Dec. 2012	Jul. 2014
West Virginia	Apr. 2017		

Notes: There is a difference between the date of medical marijuana legalization by legislation and the date on which the first medical marijuana dispensary (Sabia and Nguyen, 2018; Lu, 2021; Anderson and Rees, 2023).

Table 2: Summary Statistics

Variable	Mean	Standard Deviation
Body Mass Index (BMI)	27.335	5.562
BMI Index		
Overweight	0.629	0.483
Obesity	0.265	0.441
Medical Marijuana Laws (MML)	0.350	0.477
Recreational Marijuana Laws (RML)	0.081	0.273
Retail recreational sales allowed	0.060	0.238
Cell phone	0.325	0.468
Gender		
Male	0.509	0.499
Educational Level		
Less than high school	0.114	0.318
High school graduate	0.285	0.452
Some college	0.292	0.455
College and over	0.308	0.462
Race		
White	0.689	0.463
Black	0.106	0.308
Hispanic	0.118	0.323
Other	0.087	0.281
Marital Status		
Married	0.567	0.496
Unmarried	0.189	0.391
Divorced, etc.	0.245	0.430
Age Group		
18-29	0.197	0.398
30-39	0.196	0.397
40-49	0.190	0.392
50-59	0.172	0.377
60+	0.245	0.185
Observations	7,319,977	

Note: Data from the BRFSS, covering 1996 to 2022, are used. Weights are used in the summary statistics. Missing observations are excluded.

Table 3: Effect of RMLs on Marijuana Consumption

	(1) TWFE	(2) TWFE	(3) 2SDiD	(4) 2SDiD
RML	3.860***	3.836***	5.139***	5.107***
	(0.477)	(0.506)	(0.584)	(0.620)
Mean of Dep. Var	12.44		12.44	
Demographic Controls	Yes	Yes	Yes	Yes
MML and Rec Sale Controls	No	Yes	No	Yes
Observations	867	867	867	867

Note: *** p<0.01, ** p<0.05, * p<0.1 and robust standard errors for Columns (1) and (2) in parentheses. Columns (1) and (2), two-way fixed effect difference-in-difference regression; columns (3) and (4), two-stage difference-in-difference regression. The standard errors in parentheses are clustered at the state level in Columns (1) to (4).

Table 4: Effect of RMLs on BMI and classified BMI index

	(1) TWFE	(2) Adjusted	(3) 2SDiD	(4) Adjusted
Panel A: Body Mass Index (BMI)				
RML	-0.224***	-0.074**	-0.289***	-0.097
	(0.083)	(0.036)	(0.081)	(0.068)
Mean of Dep. Var	27.33		27.33	
Panel B: Overweight Index				
RML	-0.007	0.001	-0.010**	-0.003
	(0.004)	(0.003)	(0.004)	(0.007)
Mean of Dep. Var	0.629		0.629	
Panel C: Obesity Index				
RML	-0.012**	-0.003	-0.017***	-0.005
	(0.005)	(0.003)	(0.005)	(0.004)
Mean of Dep. Var	0.265		0.265	
Demographic Controls	Yes	Yes	Yes	Yes
MML and Rec Sale Controls	Yes	Yes	Yes	Yes
Observations	7,319,977	7,319,977	7,319,977	7,319,977

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The standard errors in parentheses are clustered at the state level in Columns (1) to (4). Weighted means of the dependent variable are reported. Columns (1) and (2) provide the estimates of two-way fixed effect model. Columns (3) and (4) present the two-stage difference-in-difference regression. Weights used in the regression analysis.

Table 5: Effect of RMLs on BMI and classified BMI index by Gender and Age Groups

	(1) Male	(2) Female	(3) 18-29 years	(4) 30-39 years	(5) 40-49 years	(6) 50-59 years	(7) 60+ years
Panel A: Body Mass Index (BMI)							
2SDiD	-0.221***	-0.370***	-0.280***	-0.284***	-0.450***	-0.360***	-0.194***
	(0.058)	(0.108)	(0.095)	(0.097)	(0.086)	(0.098)	(0.054)
Adjusted	-0.110*	-0.096	-0.012	-0.148	-0.195**	-0.148**	-0.143*
	(0.066)	(0.081)	(0.087)	(0.114)	(0.079)	(0.067)	(0.085)
Mean of Dep. Var	27.67	26.97	25.71	27.35	27.87	28.26	27.63
Panel B: Overweight Index							
2SDiD	-0.009**	-0.012**	-0.016***	-0.011	-0.013***	-0.014**	-0.002
	(0.004)	(0.005)	(0.005)	(0.007)	(0.005)	(0.006)	(0.002)
Adjusted	-0.007	-0.000	-0.002	-0.006	-0.006	-0.009**	-0.002
	(0.007)	(0.007)	(0.011)	(0.006)	(0.008)	(0.004)	(0.009)
Mean of Dep. Var	0.696	0.559	0.476	0.625	0.672	0.706	0.668
Panel C: Obesity Index							
2SDiD	-0.015***	-0.020***	-0.010*	-0.016***	-0.029***	-0.023***	-0.015***
	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)	(0.004)
Adjusted	-0.008**	-0.003	0.007	-0.007	-0.013*	-0.006	-0.013**
	(0.004)	(0.006)	(0.006)	(0.007)	(0.007)	(0.004)	(0.006)
Mean of Dep. Var	0.266	0.263	0.183	0.264	0.295	0.318	0.270
Demographic	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MML and Rec Sale	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,215,080	4,104,897	748,469	1,023,447	1,221,810	1,461,104	2,865,147

Note: *** p<0.01, ** p<0.05, * p<0.1. The standard errors in parentheses are clustered at the state level in Columns (1) to (4). Weighted means of the dependent variable are reported.

Table 6: Effect of RMLs on Vigorous Activity and Alcohol Consumption

	(1) TWFE	(2) TWFE	(3) 2SDiD	(4) 2SDiD
Panel A: Vigorous Activity				
RML	0.001	0.005	0.001	-0.001
	(0.038)	(0.006)	(0.004)	(0.003)
Observations	[7,037,487]	[7,037,487]		
Mean of Dep. Var	0.755	0.755		
Panel B: Frequency of Drinking				
RML	-9.171***	-4.375	-9.460***	-10.822***
	(3.286)	(3.311)	(3.362)	(3.675)
Observations	[6,831,048]	[6,831,048]		
Mean of Dep. Var	146.64	146.64		
Panel C: Binge Drinking				
RML	-0.042	-0.019	-0.041	-0.041
	(0.026)	(0.032)	(0.025)	(0.027)
Observations	[3,630,115]	[3,630,115]		
Mean of Dep. Var	1.102	1.102		
Demographic Controls	Yes	Yes	Yes	Yes
MML and Rec Sale Controls	No	Yes	No	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1 and robust standard errors for Columns (1) and (2) in parentheses. Columns (1) and (2), two-way fixed effect difference-in-difference regression; columns (3) and (4), two-stage difference-in-difference regression. Weights used in the regression analysis. The standard errors in parentheses are clustered at the state level in Columns (1) to (4). The number of observations used in the analysis is reported in brackets.

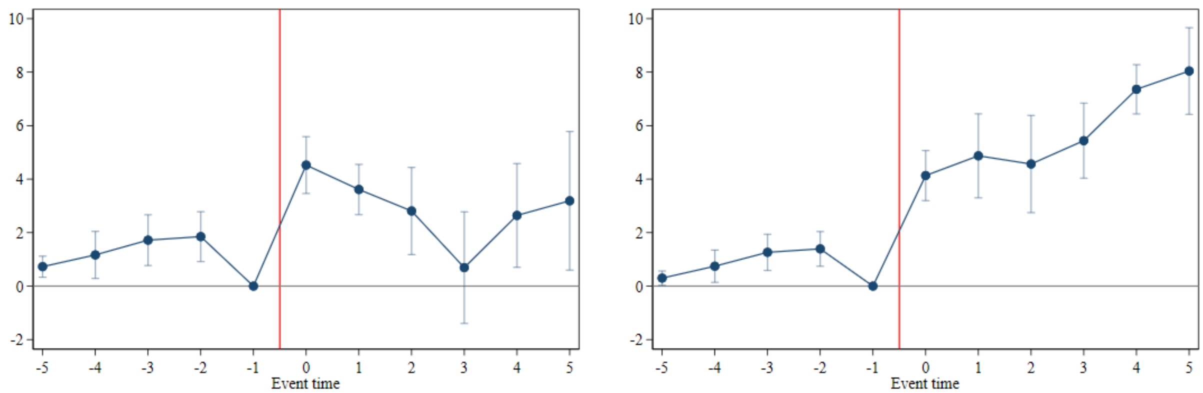
Table 7: Effect of RMLs on Spending on Food, Alcohol, and Cigarettes.

	(1) Food at Home	(2) Food Away from Home	(3) Alcohol at Home	(4) Alcohol Away from Home	(5) Cigarettes
TWFE	13.29	13.96	2.446	1.722	1.461
	(21.17)	(21.85)	(2.800)	(3.281)	(3.770)
2SDiD	55.15*	43.41	7.127*	4.777	2.989
	(22.72)	(24.48)	(3.066)	(3.879)	(3.999)
Mean of Dep. Var	745.3	1646.3	74.07	62.63	94.72
Demographic Controls	Yes	Yes	Yes	Yes	Yes
MML and Rec Sale Controls	Yes	Yes	Yes	Yes	Yes
Observations	572,026	572,026	572,026	572,026	572,026

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$ and robust standard errors for TWFE model in parentheses. Weights used in the analysis.

B Figures

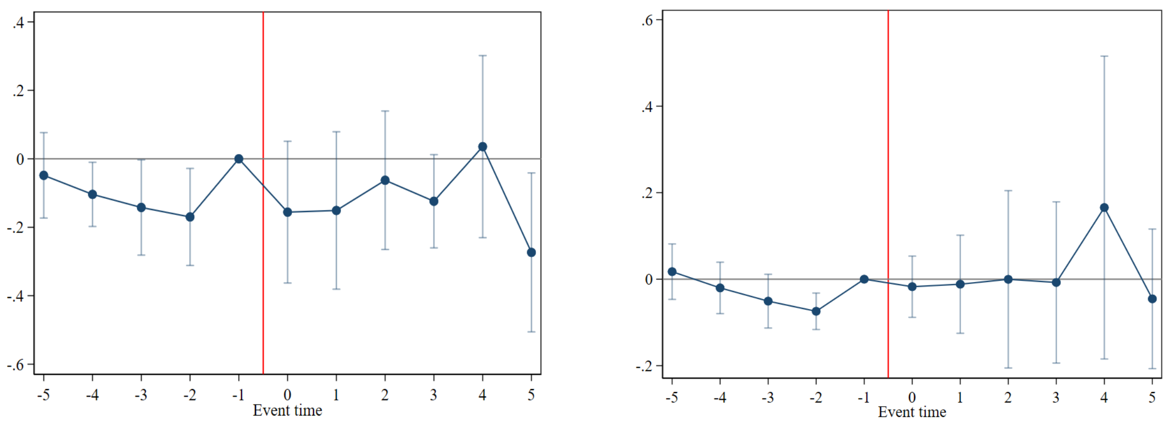
Figure 1: Effect of RMLs on Marijuana Consumption.



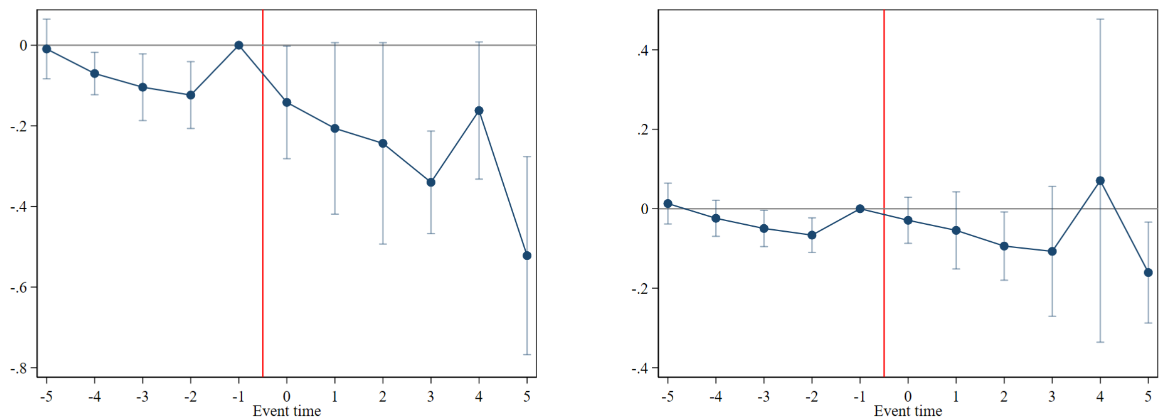
Notes: These figures plot event study, percent of the population using marijuana, NSDUH data, 2002-2018. The plot on the left presents the TWFE model, while the plot on the right shows the 2SDiD model. We include the recreational sale treatment indicator and medical marijuana law indicator. Control also includes state cigarette and alcohol tax, unemployment rate, and minimum wage by state.

Figure 2: Effect of Recreational Marijuana Laws (RMLs) on Body Mass Index (BMI)

(a) Two-Way Fixed Effects (TWFE)



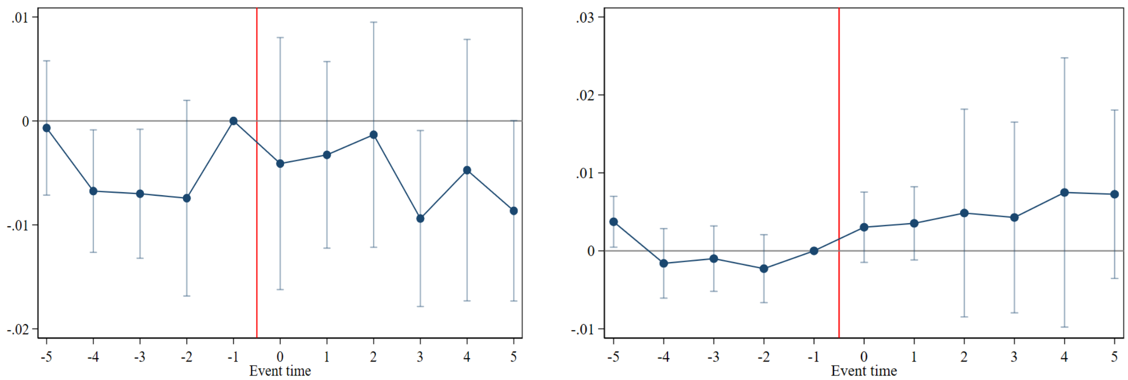
(b) Two-Stage Difference-in-Difference (2SDiD)



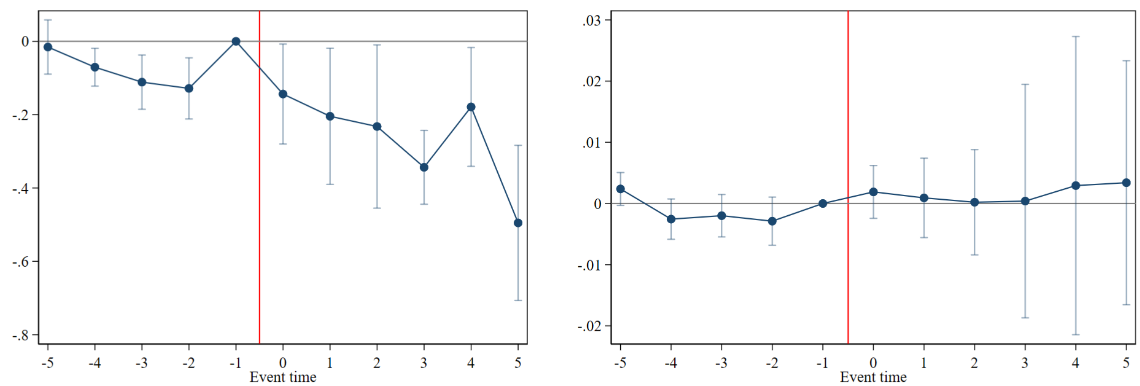
Notes: These figures present the event study model on the left and the pre-trend adjusted event study model on the right. The period beyond time 5, both before and after, is not accumulated, while the average treatment effect reflects the BRFSS data from 1996 to 2022. Control variables include a recreational sale treatment indicator, a medical marijuana law indicator, and demographic characteristics.

Figure 3: Effect of Recreational Marijuana Laws (RMLs) on Overweight Index

(a) Two-Way Fixed Effects (TWFE)



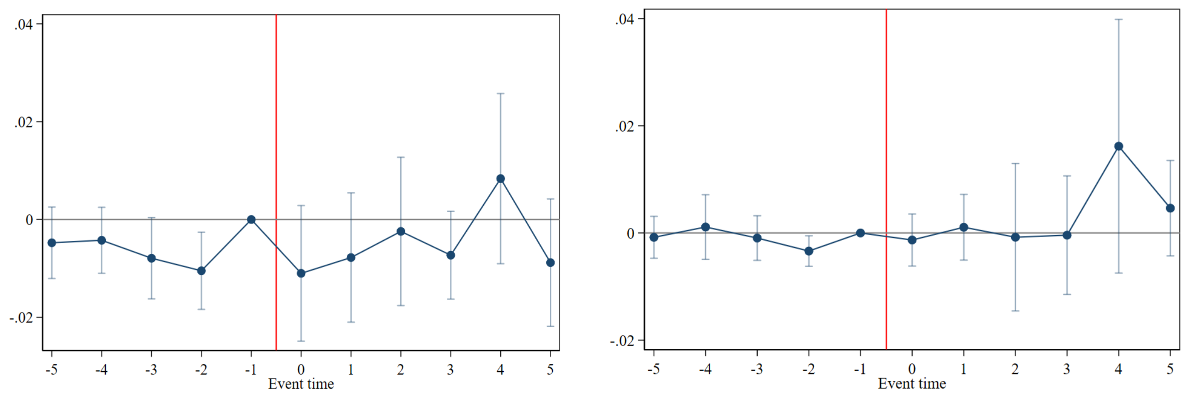
(b) Two-Stage Difference-in-Difference (2SDiD)



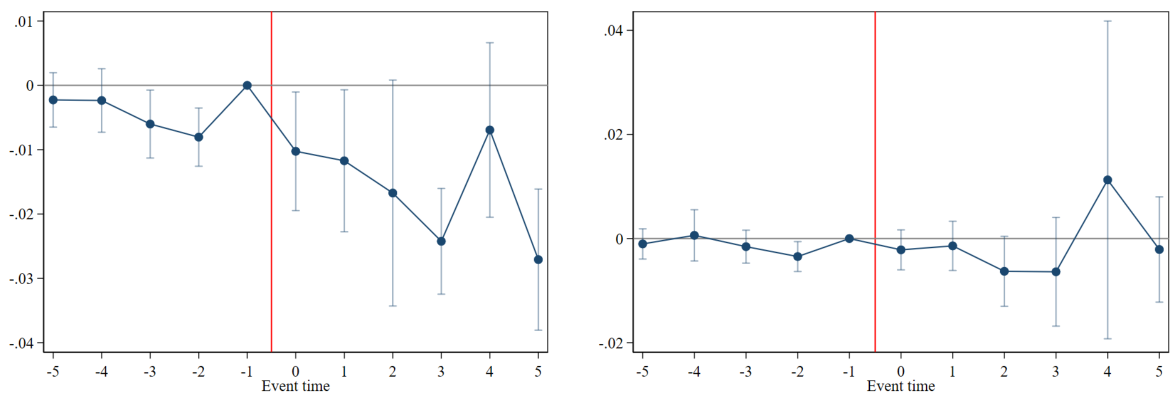
Notes: These figures present the event study model on the left and the pre-trend adjusted event study model on the right. The period beyond time 5, both before and after, is not accumulated, while the average treatment effect reflects the BRFSS data from 1996 to 2022. Control variables include a recreational sale treatment indicator, a medical marijuana law indicator, and demographic characteristics.

Figure 4: Effect of Recreational Marijuana Laws (RMLs) on Obesity Index

(a) Two-Way Fixed Effects (TWFE)

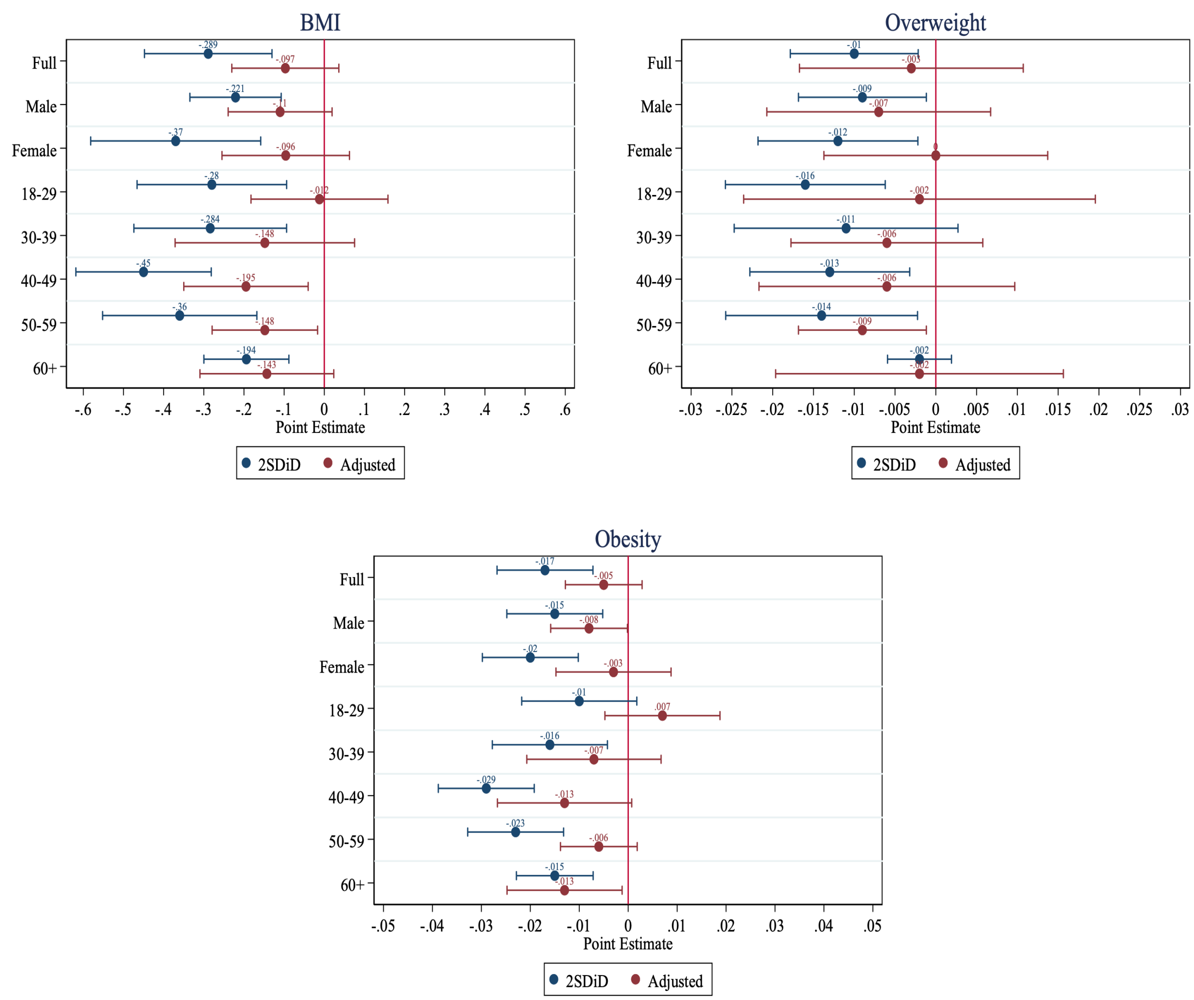


(b) Two-Stage Difference-in-Difference (2SDiD)



Notes: These figures present the event study model on the left and the pre-trend adjusted event study model on the right. The period beyond time 5, both before and after, is not accumulated, while the average treatment effect reflects the BRFSS data from 1996 to 2022. Control variables include a recreational sale treatment indicator, a medical marijuana law indicator, and demographic characteristics.

Figure 5: Effect of RMLs on BMI by Gender and Age Groups



Notes: Outcome stratified by gender and age groups. Two-stage Differences-in-Differences model with pre-trend unadjusted in blue and pre-trend adjusted in red. Controls include recreational sale treatment indicator, medical marijuana law indicator, education level, race, gender, marital status, 5-year age bin, and BRFSS cell phone survey indicator.