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Chronic Adolescent Marijuana Use as a Risk Factor for Physical and Mental Health Problems in Young Adult Men

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Some evidence suggests that youth who use marijuana heavily during adolescence may be particularly prone to health problems in later adulthood (e.g., respiratory illnesses, psychotic symptoms). However, relatively few longitudinal studies have prospectively examined the long-term physical and mental health consequences associated with chronic adolescent marijuana use. The present study used data from a longitudinal sample of Black and White young men to determine whether different developmental patterns of marijuana use, assessed annually from early adolescence to the mid-20s, were associated with adverse physical (e.g., asthma, high blood pressure) and mental (e.g., psychosis, anxiety disorders) health outcomes in the mid-30s. Analyses also examined whether chronic marijuana use was more strongly associated with later health problems in Black men relative to White men. Findings from latent class growth curve analysis identified 4 distinct subgroups of marijuana users: early onset chronic users, late increasing users, adolescence-limited users, and low/nonusers. Results indicated that the 4 marijuana use trajectory groups were not significantly different in terms of their physical and mental health problems assessed in the mid-30s. The associations between marijuana group membership and later health problems did not vary significantly by race. Findings are discussed in the context of a larger body of work investigating the potential long-term health consequences of early onset chronic marijuana use, as well as the complications inherent in studying the possible link between marijuana use and health effects.

Keywords: adolescent marijuana use, physical and mental health, long-term effects, trajectories of marijuana use, race differences

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Marijuana is the most widely used illicit drug in the United States, and ongoing political debates about legalization have caused a surge in interest regarding the potential health effects of chronic use. Although many large-scale cross-sectional studies have investigated the potential negative health effects of heavy marijuana use, relatively few longitudinal studies have prospectively examined the long-term physical (e.g., cancer, respiratory problems) and mental (e.g., psychosis, depression) health consequences of early onset chronic use (for a summary, see Volkow, Baler, Compton, & Weiss, 2014). Furthermore, many of the existing studies have produced inconsistent findings, particularly when examining marijuana use as a risk factor for cancer, cardiac illnesses, metabolic diseases, and internalizing disorders. In an effort to provide empirical evidence regarding the potential adverse consequences of marijuana legalization, the present study used longitudinal data to prospectively examine whether young men who chronically used marijuana during adolescence and young adulthood experienced a heightened risk of developing physical and mental health problems in their mid-30s.

Potential Health Consequences of Marijuana Use

Studies examining the adverse health outcomes associated with marijuana use have focused primarily on respiratory, cardiac, and metabolic problems, as well as mental health problems such as depression, anxiety, and psychosis.[1]

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[1] Although this work is outside the scope of the present article, researchers have also extensively investigated the associations between marijuana use and cognitive deficits, particularly the effect of heavy marijuana use in early adolescence (for reviews, see Lisdahl & Tapert, 2012; Volkow et al., 2014).

Cancer

Given that marijuana is typically smoked, and decades of strong research have shown that tobacco cigarette smoking is a leading cause of lung cancer (Hecht, 1999), a natural question is whether marijuana is carcinogenic (Bowles, O'Bryant, Camidge, & Jimeno, 2012; Tashkin, 2013). Marijuana and tobacco cigarettes share many of the same toxic chemicals (Tashkin, 2013), and the British Lung Foundation recently announced that the smoke produced by a marijuana cigarette might contain 50% more carcinogens than the smoke produced by a tobacco cigarette (British Lung Foundation, 2012). There is some support for a possible association between heavy (e.g., daily or near daily) and/or chronic (e.g., long-term) marijuana use and respiratory cancers, although there is little (if any) evidence indicating that light or moderate marijuana use causes cancer (see Tashkin, 2013). Some cross-sectional (Aldington et al., 2008; Berthiller et al., 2008) and longitudinal (Callaghan, Allebeck, & Sidorchuk, 2013) studies have found that heavy marijuana users are more likely to develop lung, upper airway, or oral cancer than nonusers, whereas other cross-sectional (Hashibe et al., 2006; Rosenblatt, Darling, Chen, Sherman, & Schwartz, 2004) and longitudinal (Sidney, Quesenberry, Friedman, & Tekawa, 1997) studies have failed to replicate these findings. A complication associated with these studies is that heavy marijuana users also tend to smoke tobacco cigarettes regularly, and without prospective data it is difficult to accurately delineate the potential independent influence that marijuana has on lung cancer risk. Thus, it would be premature to draw any definitive conclusions about the risk (or lack thereof) of developing cancer from marijuana use (Hashibe et al., 2005).

Respiratory System, Cardiac, and Metabolic Health

In addition to possible carcinogenic effects, there are also heightened concerns about whether marijuana is related to respiratory, cardiac, and metabolic problems. In general, research with regard to marijuana use and respiratory health has been more consistent than research on marijuana use and cardiac or metabolic illnesses.

Respiratory problems. A recent review suggests that marijuana smokers tend to experience a greater number of respiratory problems than nonsmokers (e.g., chronic bronchitis, wheezing, cough), although there is no evidence that marijuana use is related to airflow obstruction or emphysema (Tashkin, 2013). For example, one longitudinal study found that frequent marijuana use across adolescence and young adulthood was associated with an increased risk of experiencing respiratory problems (e.g., sore throat, shortness of breath) at age 27, even after controlling for age, gender, childhood aggression, adolescent major depressive disorder, parental education level and income, and maternal marijuana use (J. S. Brook, Stimmel, Zhang, & Brook, 2008). However, this study did not control for co-occurring tobacco use or the presence of respiratory problems (e.g., asthma) prior to the onset of regular marijuana use. In a cross-sectional study, researchers found that current marijuana users were more likely to report having chronic bronchitis, cough, phlegm production, wheezing, and abnormal breath sounds (without a cold) than nonusing controls, and this effect remained after accounting for the effects of gender, age, current asthma, and tobacco cigarettes used per day (B. A. Moore, Augustson, Moser, & Budney, 2005).

Cardiac and metabolic problems. Tetrahydrocannabinol, the principal psychoactive component of marijuana, is known to cause substantial increases in heart rate and moderate increases in blood pressure during intoxication (Sidney, 2002); however, studies examining the long-term (i.e., postintoxication) effects that marijuana use may have on cardiac and metabolic illnesses have produced inconsistent findings. One cross-sectional study found a dose-dependent relationship between the frequency of marijuana use (use in the past 30 days) and several cardiometabolic risk factors (e.g., elevated fasting glucose and insulin, triglycerides, systolic and diastolic blood pressure; Vidot et al., 2015). In addition, a case-crossover study of patients who suffered from a myocardial infarction found evidence that marijuana use may have triggered the attack in a small number of patients (Mittleman, Lewis, Maclure, Sherwood, & Muller, 2001), potentially because of the acute effect that marijuana use has on heart rate. However, one longitudinal study found no evidence that adolescents and adults (ages 15–49) who frequently used marijuana were at increased risk for experiencing an adverse cardiovascular event (e.g., heart attack, stroke) or developing coronary heart disease across a 10-year follow-up (Sidney, 2002). Moreover, one large-scale cross-sectional study ($N = 39{,}695$) of adults found that past and current marijuana users were actually less likely than nonusers to be diagnosed with diabetes, a well-established risk factor for cardiovascular disease (Rajavashisth et al., 2012).

Mental health. A large body of research has examined the association between marijuana use and various mental health problems. Research in this area has produced fairly consistent evidence linking marijuana use with psychotic symptoms and more mixed findings linking marijuana use with anxiety and depression.

Psychosis. Several studies have found that frequent adolescent marijuana use is associated with an increased risk for developing psychotic symptoms, particularly early onset psychosis (e.g., Casadio, Fernandes, Murray, & Di Forti, 2011; T. H. M. Moore et al., 2007; Semple, McIntosh, & Lawrie, 2005; Wilkinson, Radhakrishnan, & D'Souza, 2014). For example, a meta-analysis found that psychotic patients who used marijuana experienced an earlier onset of symptoms than psychotic patients who never used marijuana (Large, Sharma, Compton, Slade, & Nielssen, 2011). Furthermore, there is some evidence that regular marijuana use in early and middle adolescence might be a particularly salient risk factor for the development of psychotic disorders (Casadio et al., 2011; Decoster, van Os, Myin-Germeys, De Hert, & van Winkel, 2012; Hall & Degenhardt, 2000; T. H. M. Moore et al., 2007; Semple et al., 2005; Wilkinson et al., 2014), potentially because it disrupts the maturation of key brain structures in the prefrontal cortex during this developmental period (Casey, Tottenham, Liston, & Durston, 2005; Giedd, 2004, 2008; Paus, 2009; Spear, 2010). However, other evidence suggests that chronic or cumulative marijuana exposure may be more robustly related to psychotic illness than an early age of initiation (Stefanis et al., 2013). There is also evidence of a bidirectional association between prodromal psychotic symptoms (e.g., paranoia) and marijuana use during adolescence (Griffith-Lendering et al., 2013), emphasizing the importance of using longitudinal data to examine the potential influence chronic marijuana use has on the development of psychotic disorders.

Depression and anxiety. Recent reviews suggest that regular marijuana use during adolescence may be associated with an

increased risk for developing depressive symptoms, although the evidence remains somewhat mixed (for a review, see Degenhardt, Hall, & Lynskey, 2003; Moore et al., 2007). For example, several longitudinal studies found a significant relation between early marijuana use and subsequent problems with depression, even after controlling for potential confounding variables (Arseneault et al., 2002; Bovasso, 2001; D. W. Brook, Brook, Zhang, Cohen, & Whiteman, 2002; Fergusson, Horwood, & Swain-Campbell, 2002; Patton et al., 2002). However, others found no relation (Windle & Wiesner, 2004) or that the relation between marijuana and depression may be largely due to selection effects and common causal risk factors (Fergusson & Horwood, 1997; Manrique-Garcia, Zammit, Dalman, Hemmingsson, & Allebeck, 2012). For example, at least two longitudinal studies found that adolescent marijuana use was no longer significantly associated with an increased risk for later depression after controlling for several other risk factors, such as IQ, other substance use, family disadvantage, early life stressors, and deviant peers (Fergusson & Horwood, 1997; Manrique-Garcia et al., 2012). Contradictory findings have also been reported; one cross-sectional study found that individuals who used marijuana approximately once per week reported less depressed mood, more positive affect, and fewer somatic complaints than nonusers (Denson & Earleywine, 2006).

In contrast to studies on depression, very few longitudinal studies have found a significant relation between early marijuana use and the subsequent development of anxiety disorders (for a review, see T. H. M. Moore et al., 2007; Crippa et al., 2009). For example, one longitudinal study that used biannual assessments of marijuana use between ages 15 and 17 found no evidence that chronic use was related to a lifetime diagnosis of anxiety disorders during the early to mid-20s (Windle & Wiesner, 2004). The effects of marijuana use on anxiety symptoms may be more acute and isolated in nature, as high doses can cause brief episodes of panic and anxiety attacks in some individuals (Crippa et al., 2009). For others, particularly long-term marijuana users, relaxation and stress relief are often cited as primary reasons for use (Crippa et al., 2009). However, longitudinal studies often combine depressive and anxiety disorders when investigating mental health outcomes associated with marijuana use (e.g., McGee, Williams, Poulton, & Moffitt, 2000), making it difficult to identify the unique relation between marijuana and anxiety symptoms.

Limitations in Prior Research

In summary, prior research has produced mixed findings regarding the associations between chronic marijuana use and indicators of physical and mental health. If there is any trend, it is that individuals who begin using marijuana frequently during early adolescence and those who use at high frequencies throughout adolescence and young adulthood tend to develop more health problems (i.e., psychotic symptoms, respiratory problems) than infrequent/nonusers. However, many of the previously cited studies have suffered from several limitations. First, only a handful of studies have been able to prospectively delineate subgroups of individuals with varying developmental patterns of marijuana use from adolescence into young adulthood. This is particularly important given that the onset, frequency, and duration of marijuana use are posited to be influential in determining whether, and the extent to which, marijuana has a negative effect on health. Second, few longitudinal studies have examined whether young men who exhibit early and chronic developmental patterns of marijuana use are more likely to exhibit both physical and mental health problems in their mid-30s. Third, many studies have failed to control for important confounding factors, such as health problems that predated the onset of regular marijuana use and co-occurring use of tobacco, alcohol, and hard drugs. Finally, few studies have examined whether chronic marijuana use differentially affects physical and psychological health outcomes across racial groups. Given that Black men are more likely to have health problems and less likely to have access to quality health care services than White men (e.g., Williams & Collins, 1995; Williams & Jackson, 2005; Williams & Sternthal, 2010), it is possible that marijuana use among Black men could overwhelm an already compromised immune system.

The Present Study

The current study overcomes these limitations by investigating whether community-residing Black and White men who displayed different patterns of marijuana use from adolescence to the mid-20s (from age 15 to 26) exhibited different self-reported physical (e.g., asthma, high blood pressure) and mental (e.g., depression, psychosis) health problems in their mid-30s. Importantly, the associations between early patterns of marijuana use and later health were examined after controlling for several confounding factors, including socioeconomic status, co-occurring use of other substances, physical/mental health problems that predated regular marijuana use, and access to medical care. In addition, analyses examined whether Black men were more susceptible to the negative health effects of early onset chronic marijuana use than White men.

Method

Design

The present study used data from the oldest cohort of the Pittsburgh Youth Study. The Pittsburgh Youth Study is a prospective, longitudinal study designed to examine the development of delinquency, substance use, and mental health problems among young men (Loeber, Farrington, Stouthamer-Loeber, & White, 2008). In 1987–1988, the Pittsburgh public schools provided the study investigators with contact information for all enrolled seventh grade students. A random sample of seventh grade boys was selected to participate in an initial screening assessment. Parents of approximately 85% of the boys selected for the screening agreed to participate ($N = 856$). The screening assessed the boys' conduct problems (e.g., fighting, stealing) with rating scales administered to the parents, teachers, and the boys themselves. A multi-informant conduct problem score was then calculated and all boys who scored in the upper 30% ($n = 257$) were chosen for follow-up. A random sample of an approximately equal number of boys ($n = 249$) from the remaining end of the distribution was also selected for the follow-up (total number selected for study = 506 boys; 41.7% White, 54.5% Black, 3.8% other). There were no differences between boys in the screening and follow-up samples in terms of achievement test scores, parental education, and race (Loeber et al., 2008).

At the first assessment following screening, the boys were approximately 14 years old (M = 13.9 years, SD = 0.8, range 12–16 years). They were interviewed every 6 months for 2.5 years (five assessments). After the first five biannual assessments, the boys were interviewed annually for an additional 10 assessments, with the last consecutive assessment occurring when they were approximately 26 years old (M = 26.0 years, SD = 0.8, range 24–28 years). In 2009–2010, participants were reinterviewed when they averaged 36 years of age (M = 35.8 years, SD = 0.8, range 33–39 years). Retention rates are described in the Missing Data section. Greater detail on participant selection, sample characteristics, and study methodology is available elsewhere (Loeber et al., 2008).

Legal guardians provided written consent until young men were 18 years old. The boys provided informed written assent through age 17, after which they provided informed written consent. The University of Pittsburgh Institutional Review Board approved all study procedures.

Measures

Marijuana use. Marijuana was assessed with the Substance Use Questionnaire (Loeber, Farrington, Stouthamer-Loeber, & Van Kammen, 1998). At the first six assessments (screening + five biannual assessments), the young men indicated the number of days in the past 6 months that they used marijuana. To be consistent with the 10 subsequent annual assessments, we combined these biannual assessments in pairs to create three variables that represented past year marijuana use (screening + Time 1; Time 2 + Time 3; Time 4 + Time 5). During the subsequent 10 annual assessments, participants reported on the number of days in the past year they used marijuana. Because marijuana use frequency was skewed, it was recoded and treated as an ordinal variable in all analyses: 0 = *no use* (0 days), 1 = *less than once per month* (1–11 days; M [from age 15 to age 26] = 4.47, SD = 3.16), 2 = *at least monthly but not weekly* (12–51 days; M = 30.73, SD = 13.03), 3 = *1–3 times per week* (52–156 days; M = 99.40, SD = 31.19), and 4 = *more than 3 times per week* (157–365 days; M = 311.05, SD = 66.24). Descriptive statistics for the ordinal marijuana variable by age are available in online Supplemental Materials Table 1.

Screening and Time 1 marijuana use data were not included in the trajectory analysis because of the low prevalence of use at either phase (9.5%, n = 48). Therefore, the first time point for the trajectory models was the variable that represented the summed frequency of the biannual Time 2 and Time 3 assessments; boys were approximately 15 years old at Time 3 (M = 14.9 years, SD = 0.8). The young men were 26 years old (M = 26.0 years, SD = 0.8) at the last wave included in the trajectories. As such, in the analyses that follow, marijuana use was measured annually from age 15 to age 26.

Indicators of physical health problems. At the age 36 interview, participants completed a health questionnaire (Loeber et al., 2008) that asked whether they currently had the following health problems: asthma, allergies (e.g., hay fever), a heart problem, kidney disease, diabetes, headaches, high blood pressure, cancer, and sexually transmitted infections (e.g., HIV, gonorrhea, syphilis, herpes). Participants were also asked whether they were limited in any way in carrying out normal daily activities at home/work/school because of a medical condition or health problem. The young men also reported whether they ever had a heart attack or stroke, and whether they had a severe physical injury in the past year (i.e., severe burns, severe cuts, head injuries, internal injuries, and broken bones). They also reported whether they ever had a concussion, after being provided with the following definition: "A concussion is a blow to the head that causes problems with thinking or memory, like getting knocked out, being confused or disoriented, or forgetting things that happened right before or right after the blow."

Lifetime mental health disorders. At age 36, the men were interviewed using the Diagnostic Interview Schedule (Helzer & Robins, 1988) to assess lifetime diagnosis of mental health disorders based on *Diagnostic and Statistical Manual of Mental Disorders* criteria (4th ed., text revision; American Psychiatric Association, 2000). For the current study, three dichotomous variables were created to indicate whether participants had ever met diagnostic criteria for an anxiety disorder (i.e., panic disorder, agoraphobia, generalized anxiety disorder, social phobia, specific phobia, posttraumatic stress disorder, obsessive–compulsive disorder), mood disorder (i.e., major depressive episode, dysthymic disorder, manic episode, hypomania, bipolar disorder), or psychotic disorder (i.e., schizophrenia, schizophreniform disorder, schizoaffective disorder, delusional disorder, mood disorder with psychotic features, psychosis not otherwise specified).

Control variables. Several variables collected at the age 36 assessment were included as covariates in all analyses. Socioeconomic status was assessed using the Hollingshead Index (Hollingshead, 1975), which is calculated based on the participants' current occupational status and their highest education level completed. The analyses also controlled for whether men had health insurance or not (binary item). Past year use of alcohol, cigarettes, marijuana, and other hard drugs was assessed using the Substance Use Questionnaire (Loeber et al., 1998). Alcohol use was calculated by multiplying the number of days participants reported using alcohol by the average number of drinks participants consumed on drinking days (rated on 5-point ordinal scale: 0 = *less than one drink* to 4 = *six or more drinks*). This variable was log-transformed to reduce skewness. Cigarette smoking was represented by dummy coded variables to indicate whether the participant was a daily smoker in the past year, and whether the participant smoked some but not daily in the past year (the nonsmoking group served as the reference group). Marijuana use was coded in the same way as the marijuana frequency variables used in the trajectory analyses (i.e., ordinal variable: 0 = *no use* [0 days], 1 = *less than once per month* [1–11 days], 2 = *at least monthly but not weekly* [12–51 days], 3 = *1–3 times per week* [52–156 days], and 4 = *more than 3 times per week* [157–365 days]). Due to the low base rate of other illicit drug use (e.g., heroin, cocaine), a binary variable was created that indicated whether participants used any hard drugs in the past year.

For nearly all physical and mental health problems, data collected at the first assessment following screening (approximately age 14) were used to control for the presence of these problems prior to regular marijuana use. Some baseline covariates were irrelevant because only a few (if any) young boys experienced the condition by age 14 (e.g., stroke, heart attack, arthritis). At the age 14 assessment, parents completed a health questionnaire that asked whether their son had problems related to asthma, allergies, and headaches. For the physical injuries outcome, a log-transformed

variable that represented the parent-reported count of physical injuries ever experienced (same type of injuries included in the age 36 assessment) was used as a control variable. The internalizing composite scale from the parent-reported Child Behavior Checklist (Achenbach, 1991) was used as a control variable when examining anxiety and depression outcomes. To examine the psychosis outcome, we used six items from the parent-reported Child Behavior Checklist (Achenbach, 1991) to create a thought problems scale that represented the prodromal positive symptoms of schizophrenia: feels others are out to get him, hears things that are not there, sees things that are not there, behaves strangely, has strange ideas, is suspicious. This variable was log-transformed to reduce skewness.

Data Analysis Plan

Latent class growth analysis was used to identify different subgroups of marijuana users. Latent class growth analysis assumes that there are latent subpopulations of individuals who display similar developmental changes in behavior over time (B. Muthén, 2004). All latent class growth analysis models were estimated using maximum likelihood estimation with robust standard errors and were run using Mplus 7.2 (L. K. Muthén & Muthén, 1998–2012). Preliminary growth curves demonstrated that a quadratic term was the highest polynomial necessary to accurately describe change in marijuana use (specified as ordinal variables) in this developmental period. A successive number of latent classes was then specified, with the optimal number of classes determined by a number of recommended criteria, including the sample-adjusted Bayesian information criterion, Vuong–Lo–Mendell–Rubin likelihood ratio test, bootstrapped likelihood ratio test, classification accuracy, parsimony, and interpretability (Muthén, 2004; Nylund, Asparouhov, & Muthén, 2008). After the trajectory groups were established, a three-step procedure in Mplus that statistically adjusts for the uncertainty in trajectory group membership was used to examine differences on the adult health outcomes (Asparouhov & Muthén, 2013).

Missing Data

Trajectory models were estimated using maximum likelihood estimation, which accounts for missing data by estimating model parameters using all available information. The parameters are unbiased when data are missing at random, meaning that the missing data mechanism is unrelated to the unobserved outcome after controlling for observed predictors in the model (Allison, 2001). Even when the missing-at-random assumption is violated, maximum likelihood estimation is recommended over alternative methods for handling missing data, such as listwise or pairwise deletion (Allison, 2001).

Participant retention has been high across the duration of the Pittsburgh Youth Study. Fifty-four percent of individuals provided data for all phases used to estimate the marijuana use trajectories and 80% had three or fewer missing phases. At the age 36 follow-up assessment, 85% (n = 408) of the living participants were interviewed (25 participants were deceased).[2] Completers and noncompleters were similar when compared on the screening variables of high-risk status, family socioeconomic status, number of biological parents in the home, parent- and teacher-reported internalizing and externalizing problems on the Child Behavior Checklist and Teacher Report Form; the number of assessments in which marijuana use was reported, and onset of marijuana use prior to the age 15 assessment.

To facilitate a direct comparison between Black and White men, we excluded the 19 men who identified as other race from analyses predicting the health outcomes. In addition, maximum likelihood estimation does not allow for missing data on model covariates (e.g., health problems at age 14, socioeconomic status at age 36). As a result, the findings reported for the health outcomes are based on the 386 men (Black n = 212; White n = 174) who had complete data on all study covariates. However, the primary results remained unchanged when the models were rerun without covariates (see online Supplemental Materials Table 2).

Results

Descriptive Statistics for Study Outcomes

Table 1 presents descriptive statistics for the health outcomes assessed at age 36 for the total sample and separately for Black and White men. Only health outcomes for which at least 3% of the sample experienced the condition were included in the final analytic models. The most common health problems reported were experiencing a prior concussion (27.7%) and current allergies (18.8%). The least common health problems reported were having a sexually transmitted disease (0.8%) and kidney disease (0.3%).

Trajectory Groups

The adjusted Bayesian information criterion, entropy, Vuong–Lo–Mendell–Rubin likelihood ratio test, and bootstrap likelihood ratio test corresponding to models with two to five latent trajectory groups are presented in Table 2. A four-group solution was selected based on model fit statistics, substantive interpretation, face validity of classes, parsimony, and consistency of findings with prior research (White, Jackson, & Loeber, 2009). The specific classes were low/nonusers (46.2%, average posterior probability [pp] = .9), adolescence-limited users (10.7%, pp = .8), late increasing users (21.0%, pp = .8), and early onset chronic users (22.0%, pp = .9). Black men were significantly more likely than White men to be in the late increasing group compared with the low/nonuser group (multinomial regression; odds ratio = 1.39, p = .007), with no other significant race differences among groups. To illustrate group differences in marijuana use patterns, we hard classified participants into their most likely trajectory group, and plotted a graph depicting the average number of days using marijuana in the past year (see Figure 1).

Physical Health Outcomes

Results examining marijuana trajectory group differences on physical health outcomes after controlling for model covariates are

[2] Marijuana trajectory groups did not differ in whether the young men died before the age 36 assessment, $\chi^2(3) = 4.6$, p = .204. Of the 25 deceased men, the deaths were due to gun homicide (n = 18), nongun homicide (n = 3), accident related to delinquency (n = 1), accident unrelated to delinquency (n = 1), natural causes (n = 1), and unknown cause (n = 1).

Table 1
Health Outcome Descriptive Statistics (in Percentages)

Outcome	Total sample	Black	White
Physical health problems			
Asthma	6.7	7.5	5.7
Allergies	18.8	19.2	18.3
Heart problem	1.8	1.4	2.3
Kidney disease	0.3	0.0	0.6
Diabetes	2.3	4.2	0.0
Headaches	10.6	9.9	12.0
High blood pressure	11.9	14.6	8.6
Cancer	0.8	0.9	0.6
Sexually transmitted infection	0.8	0.5	1.1
Limited in physical activities	5.2	4.7	5.7
Heart attacks/strokes lifetime	1.3	0.9	1.7
Physical injury in past year	9.8	7.1	13.1
Concussion lifetime	27.7	19.9	37.1
Lifetime mental health disorders			
Anxiety disorder	8.3	9.4	6.9
Mood disorder	5.7	5.7	5.7
Psychotic disorder	3.4	3.8	2.9

Note. Descriptive statistics are based on data from all men who completed the age 36 assessment. Total sample = Black and White only.

presented in Table 3. The trajectory groups were not significantly different in terms of self-reported asthma, allergies, headaches, and high blood pressure. The groups also did not differ in terms of having a current health condition that limited their physical activities, having a serious physical injury in the past year, or having a prior history of concussion. Black men were more likely to report having high blood pressure than Whites. White men were more likely to report having experienced a serious physical injury in the past year and having a past history of concussion. Results depicting the association between the model covariates and the physical health outcomes are reported in online Supplemental Materials Table 3.

Mental Health Outcomes

Results examining marijuana trajectory group differences on mental health outcomes after controlling for model covariates are also presented in Table 3. There were no marijuana trajectory group differences related to a lifetime diagnosis of anxiety disorders, mood disorders, or psychotic disorders. There were also no significant differences between Black and White men on the mental health outcomes. Results depicting the association between the model covariates and the mental health outcomes are reported in online Supplemental Materials Table 3.

Table 2
Model Comparisons for Successive Latent Classes of Marijuana Use Trajectories

Model	BIC adjusted	Entropy	Vuong–Lo–Mendell–Rubin likelihood ratio test	Bootstrapped likelihood ratio test
2-class	9114.40	0.87	$p < .001$	$p < .001$
3-class	8922.80	0.80	$p = .188$	$p < .001$
4-class	8793.92	0.82	$p = .001$	$p < .001$
5-class	8728.84	0.80	$p = .533$	$p < .001$

Note. BIC = Bayesian information criterion. The Vuong–Lo–Mendell–Rubin likelihood ratio test and the bootstrapped likelihood ratio test examine whether a N group solution is better than $N - 1$ group solution.

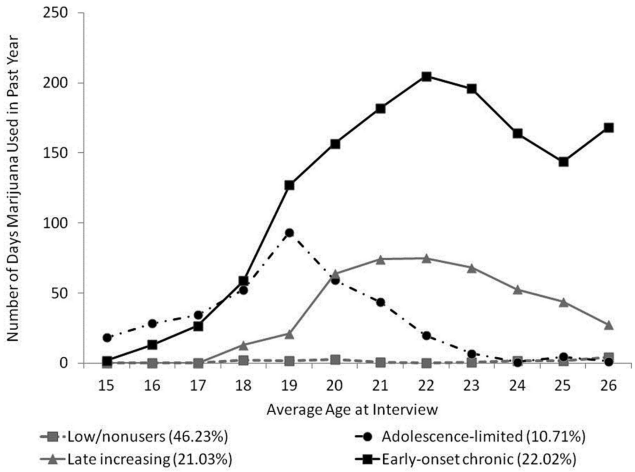

Figure 1. Mean frequency of past-year marijuana use by age for each trajectory group.

Race Differences and Health Outcomes

The last stage of the analysis investigated whether the associations between marijuana trajectory group and health outcomes differed for Black and White men. There were no significant interactions between race and marijuana trajectory group membership when predicting the study outcomes (these data are not presented here but are available from the first author on request).

Discussion

Ongoing debates about the legalization and decriminalization of medical and recreational marijuana have precipitated a need for rigorous scientific evaluations of the potential long-term consequences associated with chronic marijuana use. The present study used prospective, longitudinal data that spanned more than 20 years to examine whether patterns of marijuana use from adolescence to young adulthood were related to indicators of physical and mental health in adulthood. After controlling for potential confounding variables such as alcohol, tobacco, and hard drug use, socioeconomic status, whether the young men had health insurance, and early health status (prior to marijuana use), findings from this sample indicated that chronic marijuana users were not more likely than late increasing users, adolescence-limited users, or low/nonusers to experience several physical or mental health problems in their mid-30s. In fact, there were no significant differences between marijuana trajectory groups in terms of adult health outcomes, even when models were run without controlling for potential confounds. This is particularly striking given that men in the early onset chronic group were using marijuana (on average) once per week by late adolescence and continued using marijuana approximately 3–4 times a week from age 20 to 26 years.

Table 3
Health Outcomes by Trajectory Group

Outcome	Low/nonusers (n = 186)		Adolescence limited (n = 38)		Late increasing (n = 76)		Early onset chronic (n = 86)		Trajectory group	Black vs. White
	Pr	*SE*	*Pr*	*SE*	*Pr*	*SE*	*Pr*	*SE*	χ^2	*z*
Physical health problems										
Asthma	.05	.02	.13	.07	.06	.03	.06	.04	2.61	0.84
Allergies	.19	.04	.08	.05	.10	.03	.12	.05	5.17	1.96
Headaches	.11	.03	.15	.07	.01	.01	.06	.03	6.52	−0.70
High blood pressure	.11	.03	.06	.04	.11	.04	.08	.04	1.24	2.07*
Limited in physical activities	.03	.02	.03	.02	.02	.02	.01	.01	1.71	−1.02
Physical injuries	.07	.03	.07	.04	.09	.04	.12	.05	1.91	−2.13*
Concussions (ever)	.27	.04	.17	.06	.19	.05	.29	.07	3.57	−3.26**
Lifetime mental health disorders										
Anxiety disorder	.07	.02	.10	.05	.04	.02	.06	.03	1.95	1.02
Mood disorder	.06	.02	.02	.02	.02	.02	.05	.03	2.08	0.22
Psychotic disorder	.02	.01	.03	.04	.02	.01	.02	.02	.71	0.39

Note. *Pr* = predicted probability of event occurrence. All effects are after controlling for model covariates. Only Black and White men with complete data on model covariates are included in the analyses. Sample sizes for each trajectory group are based on class assignment using the posterior probability of group membership.
* $p < .05$. ** $p < .01$.

The four latent marijuana use trajectory groups identified in the current study are very similar to those observed in prior longitudinal investigations. Specifically, prior studies have also found that there is a relatively small subgroup of early onset chronic users who initiate regular use in early to mid-adolescence and continue to engage in frequent marijuana use into early adulthood (J. S. Brook, Zhang, & Brook, 2011; Ellickson, Martino, & Collins, 2004; Finlay, White, Mun, Cronley, & Lee, 2012). Similar to the current findings, there also tends to be a group of adolescence-limited users who exhibit regular marijuana use beginning in early to mid-adolescence, but experience a precipitous decrease in their use beginning in their early to mid-20s (J. S. Brook et al., 2011; Finlay et al., 2012; Guo et al., 2002; Kandel & Chen, 2000). Lastly, prior studies often delineate a group of late increasing users who gradually begin engaging in frequent marijuana use during late adolescence and continue using regularly during their 20s and 30s (J. S. Brook et al., 2011; Ellickson et al., 2004; Finlay et al., 2012; Guo et al., 2002; Kandel & Chen, 2000). Although prior studies have found that this late increasing group sometimes uses marijuana more frequently in adulthood than youth who exhibit early onset chronic use, this was not the case in the current study. Instead, the average annual frequency of marijuana use among men in the early onset chronic group was roughly 2–3 times greater than that of men in the late-onset group from the early to mid-20s.

Just as the trajectories identified in the current investigation are consistent with prior studies, others studies have also found that chronic marijuana use may not be significantly related to long-term physical or mental health problems (e.g., Sidney, 2002; Sidney et al., 1997; Windle & Wiesner, 2004). Similar to Windle and Wiesner (2004), the present study indicated that early onset chronic marijuana use was not significantly associated with an increased risk for developing depression or anxiety disorders in early adulthood. Although one study found that individuals who exhibited a chronically high trajectory of marijuana use over time ("persistent users") were more likely to be diagnosed with depression in adulthood than other marijuana users (Juon, Fothergill, Green, Doherty, & Ensminger, 2011), this discrepancy may be due to methodological differences. In the current study, annual interviews were used to collect information regarding the number of days participants used marijuana in the past year from adolescence into their mid-20s. The analysis presented here also controlled for possible confounding variables, including internalizing symptoms in early adolescence. The study by Juon and colleagues (2011) did not control for early internalizing symptoms, and they used retrospective reports of the age at first time using marijuana and age at last time using marijuana. All years between the first and last time using were coded as "marijuana using" years, and these binary items were used to model the trajectory groups. As such, the analytical strategy in Juon and colleagues may have overestimated marijuana use and inflated the relation between marijuana trajectory groups and depression.

Given prior research in the area, it was somewhat surprising that marijuana groups did not differ in the likelihood of having a psychotic disorder. However, there are important methodological differences between the current study and prior work in the area. First, many previous studies examined the association between marijuana use and the onset of psychotic symptoms using retrospective reports collected from patients with a psychotic disorder (see Di Forti et al., 2014; Large et al., 2011). For example, a meta-analysis that synthesized data from more than 80 studies found that, among patients diagnosed with psychosis, marijuana users observed the onset of their psychotic symptoms to appear about 2.7 years before symptoms appeared for nonusers (Large et al., 2011). This could suggest that marijuana exacerbates a preexisting disposition for psychosis but does not cause the disorder to develop in nonvulnerable individuals. It is also possible that the focus on a diagnosis of a psychotic disorder in the current study limited the power to detect more subtle effects that marijuana use has on thought problems. The present study might have found group differences if a lower threshold was used, such as prodromal psychotic symptoms (e.g., excessive suspiciousness, odd think-

ing), instead of a binary diagnostic variable. Furthermore, many prior studies examined chronic marijuana dependence and abuse as a risk factor for later psychotic disorders (e.g., Agosti, Nunes, & Levin, 2002; Farrell et al., 2002; Hall & Degenhardt, 2000) rather than the frequency of use, which may have contributed to the discrepant findings.

Another potential difference between the present study and prior work regarding the marijuana–psychosis link is that many prior studies used cross-sectional data and retrospective reports (e.g., Agosti et al., 2002; Davis, Compton, Wang, Levin, & Blanco, 2013; Di Forti et al., 2014; Farrell et al., 2002; Hall & Degenhardt, 2000; Miller et al., 2001). Although there have been a handful of large-scale prospective population-based and birth cohort studies conducted around the world (e.g., Sweden, Netherlands, New Zealand, Germany, United Kingdom), almost all of these studies collected marijuana data at one to three time points and assessed whether these scores were associated with psychotic outcomes between 1 and 35 years later (e.g., Andréasson, Engström, Allebeck, & Rydberg, 1987; Arseneault et at., 2002; Caspi et al., 2005; Fergusson, Horwood, & Beautrais, 2003; Henquet et al., 2004; Kuepper et al., 2011; Manrique-Garcia et al., 2012; van Os et al., 2002; for a review, see T. H. M. Moore et al., 2007). None of these studies (to our knowledge) investigated whether the developmental course of marijuana use between adolescence and young adulthood is related to psychotic outcomes in adulthood. The current study investigated whether subgroups of individuals who followed different patterns of marijuana use from adolescence to young adulthood had different likelihoods of having a psychotic diagnosis in adulthood. This is a fundamentally different analysis than what has been researched in prior work. Investigating similar questions, with different methods, moves the field forward by demonstrating the specific aspects of marijuana use that are (and are not) related to psychotic outcomes.

Finally, it is increasingly being recognized that individual differences likely moderate the association between marijuana use and psychotic disorders. For example, some studies have found that genetic liability affects whether, for whom, and the extent to which, marijuana has a negative influence on mental health. Alleles on at least two genes known to affect dopamine processing, catechol-O-methyltransferase and C-alpha serine/threonine-protein kinase, have been identified as potential moderators of the link between marijuana use and psychosis (Caspi et al., 2005; van Winkel & the Genetic Risk and Outcome of Psychosis Investigators, 2011; but see Decoster et al., 2012, for a review). However, attempts to replicate the catechol-O-methyltransferase genetic finding have been unsuccessful (Costas et al., 2011; Kantrowitz et al., 2009; Zammit, Owen, Evans, Heron, & Lewis, 2011; Zammit et al., 2007). Future studies should continue investigating the complex role of genetic factors in understanding the linkage between marijuana use and aspects of physical and mental health.

The present study found no evidence that race moderated the associations between marijuana use and the adult health outcomes examined. However, evidence did indicate that Black men were more likely to report having high blood pressure than White men, consistent with prior studies examining racial health disparities in the United States (Williams & Jackson, 2005; Williams & Sternthal, 2010). Although differences in socioeconomic status are believed to partially account for racial differences in hypertension (Williams & Collins, 1995), the current finding remained significant after controlling for participants' current occupational status and their highest level of education completed.

Study Limitations

Although the present study generated consistent findings across a variety of indicators of health, the results should be interpreted with caution because of several limitations. First, the lack of group differences may have been due to selection effects. It is possible that individuals who had a higher risk of developing marijuana-related health problems chose to use less marijuana and individuals who had a lower risk of developing marijuana-related health problems chose to use more marijuana (thus masking the health risks associated with use). Future research is needed to determine whether (and the extent to which) individuals systematically calibrate their marijuana use based on their understanding of their risk for subsequent mental and physical health problems, based on their perception of the risks associated with the drug, and based on their subjective appraisal of their physical and psychological reaction to marijuana. Similarly, it is important to emphasize that the findings generated in the present analysis extend only to those who chose to use marijuana, as these findings might not be representative of risk in the general population. In summary, the inability to randomize youth to different marijuana use conditions limits the conclusions that can be drawn regarding the health risks associated with use or lack thereof. Furthermore, given the current political climate, some particularly relevant factors (e.g., perceived safety of the drug, legalization, availability) might alter or expand the population of marijuana users, which might directly or indirectly affect the extent to which marijuana is (or is not) related to the health outcomes studied here.[3]

In addition, the sample was obtained from one geographic area, and analyses were limited to Black and White men. Thus, the analyses presented here need to be replicated with more diverse samples. Given potential sex differences in health disparities, it is also important to study the health effects of marijuana for women. This is especially important given that research indicates that women experience more serious health complications from substance use than men (Kay, Taylor, Barthwell, Wichelecki, & Leopold, 2010).

Furthermore, the current study assessed health outcomes in the mid-30s, which may be too early for decrements in health to emerge. In fact, there were few men with current or chronic conditions within the sample, limiting the power to examine some of the outcomes that were assessed. Therefore, continued data collection and longer follow-ups are needed. In addition, as mentioned previously, the base rates of many of the outcome variables were low. These low base rates limited the ability to detect small, yet potentially important, effects of marijuana use on health. Also, given that the mental health outcomes in the present study were binary diagnostic variables, the data presented here do not address whether, and the extent to which, marijuana use might be associ-

[3] We thank an anonymous reviewer for pointing out the limitations outlined in this paragraph.

ated with elevated (or reduced) internalizing or psychotic symptoms. As mentioned previously, significant effects of marijuana may have become apparent if symptom counts were used instead of diagnostic indicators.

Another limitation of the current study is that all health outcomes were measured by self-report. It is possible that some young men had not seen a doctor and thus were unaware of their health problems. Future research should use physician evaluations and medical testing as part of a more comprehensive assessment of physical health outcomes. Furthermore, the mental and physical health problems included were not comprehensive and some potential negative consequences may have been omitted.

It is also important to note that the marijuana trajectory groups were delineated based on the frequency of use and did not take into account quantity, quality, or potency of marijuana. The combination of frequency, quantity, and potency may be especially important when examining health outcomes. The marijuana data in the current study were collected in the 1990s and early 2000s and the average tetrahydrocannabinol potency in marijuana confiscated by U.S. federal and state law enforcement agencies has increased dramatically in the last two decades (e.g., Mehmedic et al., 2010). Higher potencies of marijuana might have a stronger effect on mental and physical health outcomes. Conversely, individuals might be exposed to less smoke overall if more potent marijuana causes individuals to need less of the drug to receive the same high. As such, future research should examine the associations between marijuana and health with varying potencies and types of marijuana.

Conclusion

Over the past decade, U.S. policies have increasingly shifted toward a deregulation of marijuana for medical and recreational use. Recent legislation in several states (i.e., Colorado, Washington, Oregon, Alaska) and Washington, D.C., has legalized recreational marijuana use for individuals 21 and older. More states (e.g., California) are likely to follow suit in future elections. Given this shift in the political climate and the potential increase in marijuana use among youth, it is critical to empirically evaluate the long-term physical and mental health consequences of marijuana use. Overall, data from this sample provide little to no evidence to suggest that patterns of marijuana use from adolescence to young adulthood, for the Black and White young men in the present study, were negatively related to the indicators of physical or mental health studied here. This does not discredit the work of others. It could be the case that cumulative tetrahydrocannabinol exposure, age of initiation of use, or use at one particular age is more predictive of negative health outcomes than the overall pattern of use between adolescence and adulthood.

In conclusion, the health outcomes associated with marijuana use are just one piece of the legalization puzzle. Political debates surrounding the legalization of this drug also need to consider the potential effects on many other domains such as cognitive and intellectual functioning, alterations in brain function and structure, academic and occupational failure, psychosocial adjustment, antisocial and criminal behavior, motor vehicle accidents, and suicidal ideation. Many of these outcomes have been discussed elsewhere (see Meier et al., 2012; Volkow et al., 2014) and were beyond the scope of the present study, which focused only on health outcomes. Indeed, marijuana policymakers and stakeholders need to consider the results of any single study in the context of the larger body of work on the potential adverse consequences of early onset chronic marijuana use.

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Clarification to Bechtold et al. (2015)

For the article "Chronic Adolescent Marijuana Use as a Risk Factor for Physical and Mental Health Problems in Young Adult Men" by Jordan Bechtold, Theresa Simpson, Helene R. White, and Dustin Pardini (*Psychology of Addictive Behaviors*, 2015, Vol. 29, No. 3, pp. 552–563. http://dx.doi.org/10.1037/adb0000103), planned analyses using a Wald joint significance test examined whether four adolescent marijuana use trajectory groups differed on self-reported physical and mental health outcomes assessed at age 36. This omnibus test indicated that the groups did not significantly differ in terms of their probability of reporting targeted health problems.

The results from this study generated considerable controversy, including requests for supplemental analyses. One issue was related to whether group differences exist if the three marijuana trajectory groups (i.e., early onset chronic, late increasing, adolescence-limited) are combined and compared to the low/no use group on outcomes in models without any covariates, as well as in models controlling for a reduced set of covariates consisting of race and preexisting health problems at age 13.

Table 1 presents these supplemental analyses. In models without covariates, the three marijuana trajectory groups combined were significantly more likely to report experiencing asthma and less likely to report experiencing allergies relative to the low/no use group. After controlling for race and preexisting health problems at age 13 (data not shown; available from authors), the group difference for allergies remained statistically significant ($p = .04$) but the difference for asthma did not ($p = .10$). In the unadjusted and adjusted models, the three marijuana groups combined had a slightly higher probability of reporting a lifetime psychotic disorder than the low/no use group, but the difference did not reach statistical significance in either model.

Because of concerns that maximum likelihood estimation can produce parameter biases with low base-rate outcomes, we compared the combined marijuana use group with the low/no use group on the lower base-rate outcomes (<10%) using Firth's penalized likelihood logistic regression for rare events (Heinze & Schemper, 2002). In these models, participants were hard classified into the combined marijuana use group or the low/no use group based on their highest posterior probability of group membership (no adjustment for class uncertainty). As seen in Table 1 (right), the models without covariate adjustment for lower base-rate outcomes were very similar (almost identical) to the standard logistic regressions. When race and preexisting health were included (data not shown), group differences for asthma were no longer significant ($p = .14$) and the p value for psychotic disorder remained largely unchanged ($p = .10$).

This reanalysis suggests that, in general, the three marijuana-using groups combined were not significantly different from the low/no use group on the health outcomes. The group difference on psychotic disorder approached statistical significance and would have been significant if a more liberal test (i.e., one-tailed) was utilized.

As noted in the original manuscript, there are important limitations that need to be considered: (a) The sample included young men who were using marijuana in the late 1990s and early 2000s and THC content has risen recently; (b) data were obtained from self-reports; (c) power was low, particularly for low base-rate outcomes, such as psychotic disorders; and (d) causal and even temporal inference in observational studies is inherently limited. It is important to keep in mind that many other studies have found associations between heavy marijuana use and various mental and physical health problems, particularly psychotic disorders (Semple, McIntosh, & Lawrie, 2005; Volkow, Baler, Compton, & Weiss, 2014; Wilkinson, Radhakrishnan, & D'Souza, 2014).

Table 1

Unadjusted Models Comparing the Low/No Marijuana Use Group to the Other Three Marijuana Use Groups Combined on Adult Health Outcomes

	FIMLE with robust standard errors[a]						Firth's penalized likelihood[b]			
	Marijuana use groups		Low/No use				Marijuana use groups	Low/ No use		
	Pr	(*SE*)	*Pr*	(*SE*)	Wald	*p*	*Pr*	*Pr*	*z*	*p*
Physical health problems										
Allergies	0.14	(0.03)	0.23	(0.03)	4.10	0.043				
Asthma	0.10	(0.02)	0.04	(0.01)	5.05	0.025	0.10	0.04	2.11	0.035
Headaches	0.08	(0.02)	0.13	(0.03)	1.71	0.191				
High blood pressure	0.11	(0.02)	0.12	(0.02)	0.23	0.629				
Limited in physical activities	0.05	(0.02)	0.05	(0.02)	0.02	0.882	0.05	0.06	−0.19	0.847
Physical injuries	0.11	(0.02)	0.09	(0.02)	0.54	0.462	0.11	0.09	0.76	0.448
Concussions	0.24	(0.03)	0.29	(0.03)	0.84	0.361				
Lifetime mental health disorders										
Anxiety disorder	0.09	(0.02)	0.08	(0.02)	0.34	0.559	0.09	0.08	0.48	0.631
Mood disorder	0.04	(0.02)	0.07	(0.02)	1.07	0.302	0.05	0.07	−0.63	0.527
Psychotic disorder	0.05	(0.02)	0.02	(0.01)	2.88	0.089	0.05	0.02	1.69	0.092

Note. Marijuana use groups = Three marijuana using groups combined (early onset chronic, late-increasing, adolescence-limited); Pr = predicted probability; SE = standard error (standard errors not available for post estimation predicted probabilities in Firth's logistic).

[a] Models run using full information maximum likelihood estimation with robust standard errors (Marijuana use group: $N = 259$; Low/No use: $N = 226$). [b] Firth logistic regression using penalized maximum likelihood estimation conducted for low base rate events (i.e., <10%). Sample size reduced to 385 (Marijuana use group: $N = 200$; Low/No use: $N = 185$) because penalized maximum likelihood logistic regression does not allow for missing data on the dependent variable.

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