CONTRIBUTIONS TO EPIDEMIOLOGICAL RESEARCH ON THE SELLING OF INTERNATIONALLY REGULATED DRUGS

By

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ABSTRACT

CONTRIBUTIONS TO EPIDEMIOLOGICAL RESEARCH ON
THE SELLING OF INTERNATIONALLY REGULATED DRUGS

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My dissertation research project is focused upon a topic of person-to-person spread that has been central in epidemiological research for more than 100 years. Here, I consider person-to-person spread of drug use when young people are selling internationally regulated drugs (IRD) such as cannabis, cocaine, and opioids. I present empirical estimates that should help guide public health and public safety tactics intended to reduce drug overdoses and other IRD-related casualties.

I am not the first to study person-to-person spread via youthful drug selling, but most prior contributions have not had an epidemiological frame, and instead can be characterized as relatively small sample ethnographic or social science investigations of the type illustrated in 'The Road to H.' In that book, Isidore Chein and his collaborators (1964) described drug selling by New York City youths in the early-mid 1950s.

This doctoral dissertation research project builds upon that prior work. The first of my four investigations estimates the age-specific prevalence of recent drug selling behaviors during adolescence, with attention to hypothesized subgroup variations suggested by Salas-Wright and colleagues (2017). Next, I produced estimates to disclose birth cohort variations in drug selling prevalence. Next, I focused on antecedent drug histories and whether the occurrence of drug selling varies across subgroups defined by prior IRD experiences. Finally, I estimated the likelihood of recent drug-selling across strata defined by duration of prior IRD use and produced estimates to compare drug selling experiences of never users versus other IRD-using subgroups.

Based entirely upon novel analyses of public use datasets from the US National Surveys of Drug Use and Health, my main findings are as follows:

- Study 1: Estimated drug selling prevalence shows age-related increases but estimates for males are larger than estimates for females.
- Study 2: Estimated age-specific prevalence patterns do not vary appreciably across recent birth cohorts.
- Study 3: Starting to use cannabis and no other IRD is associated with greater odds of drug selling in the subsequent adolescent years. The study estimates suggest that as time passes since first IRD use, the odds of drug selling increase (up to a point). If the first IRD use is not cannabis, then the estimated odds of drug selling may be larger than if cannabis is the only IRD that has been used.
- Study 4: Adolescents who start to use cannabis but none of the other internationally regulated drugs are observed to be more likely to sell drugs in the second year after the first use, compared to adolescents who have never used any drug.

Subject to limitations described in this dissertation report, these findings merit further investigation and attention in public health initiatives to prevent the person-to-person spread of drug use during adolescence. I offer ideas for future research directions that can build upon this project's findings, with concrete examples of potentially useful longitudinal and prospective investigations.

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

The well-being of children, including adolescents, is one of the most significant concerns for society. Transitioning from childhood to adulthood is a troublesome life stage in nearly every society. This problem is even worsening in modernized societies due to drugs. Drug use by youth and delinquency associated with drugs, especially drug selling, are significant problems in the US and most other western countries and have been so for many decades. Although the specific drugs of choice and the associated rates of drug selling fluctuate based on locations and historical contexts, such misbehavior of children and adolescents has been a major concern of public health, public policy, and government bodies since at least the middle of the 20th century.

There is an undeniable link between drug use and drug selling, although the causal relationships remain somewhat unclear, particularly concerning temporal sequencing. Multiple studies have shown that the adverse effects of those two strongly correlated behaviors, including but not limited to impaired school performance, involvement of the criminal justice system, engaged of gang, physical or sexual abuse, and chemical dependence (Gordon et al., 2014; Vaughn et al., 2015; Wilson et al., 1993).

In my scholarly review of the published literature on the epidemiology of drug selling, I found a mid-20th century research monograph (Chein et al., 1964) that summarized prior empirical contributions on the topic of drug selling. According to the research monograph, first-time heroin use was associated with drug selling -- adolescents involved in heroin use often conducted drug

dealing. But most evidence on drug selling comes from criminological studies of gangs and relatively small samples of adolescents without guidance from the concepts, principles, and research approaches of epidemiology.

Few people have thought about adolescent drug selling from an epidemiological perspective and the need to draw on public health control methods when interventions are designed. For this reason, a comprehensive view of the epidemiology of drug involvement should not neglect drug selling.

The current investigation seeks to explore the relationship between age and cohort. I will provide a dynamic view of each cohort because sometimes, the patterns of occurrence of drug selling, cohort by cohort, might not be the same as what is seen in the age-specific patterns of drug selling experiences. My research on this topic will also produce estimates for variations by sex (males versus females) and for U.S. Census categories of race-ethnicity. I also will examine whether the type of internationally regulated drugs (IRD) first used (cannabis vs. non-cannabis IRD) might have a relationship to the odds of being a recent drug seller during the adolescent years.

1.2 Specific Aims

In the spirit of providing epidemiological estimates to help the field design prospective cohort studies or longitudinal repeated measures projects to study drug selling pathways, I proposed this doctoral dissertation research project with three specific aims.

Aim 1: To estimate the age-specific prevalence of recent drug selling behaviors by age from 12 to 17 years in the non-institutionalized U.S. population, with attention to potential variations associated with (a) being male, (b) being an older adolescent, and (c) self-identification subgroups defined by the US Census as ‘race-ethnicity.’

Hypothesis 1: Estimated drug-selling prevalence is expected to increase as age increases, be greater for males (versus females), and vary across US Census race-ethnicity subgroups.

Aim 2: Transform age-and-year specific prevalence estimates from Aim 1 to make a birth-cohort-and-age specific forecast and to examine estimates for a set of birth cohort experiences as each cohort increases in age.

Hypothesis 2: The drug-selling estimates for the birth cohort (specified by age and year) might vary across the cohorts and years under study in this dissertation research project.

Aim 3: Beginning with the 12-year-old adolescents, and then looking age-by-age to the 17-year-old adolescents, (i) to estimate the extent to which the odds of being a recent drug seller may vary for the elapsed time since the onset of IRD use; (ii) estimate the extent to which the odds of being a recent drug seller may depend on whether the subject has ever used IRD and vary with the type of drug at the first IRD use; (iii) use trend analysis and meta-analysis to summarize the estimates year-by-year from 2002 to 2019.

Hypothesis 3: The estimated relative odds of being a recent drug seller might be null or might vary across subgroups defined by the IRD drug subtype first used (e.g., cannabis-only users versus adolescents who used some other IRD extra-medically with or without cannabis).

Aim 4: To address temporal sequencing issues by comparing drug selling odds estimates for never users versus users whose first drug experience is restricted to cannabis onsets that occur 12-15 months before the assessment of recent drug selling.

Hypothesis 4: Never users will not experience any appreciable variation in the odds of drug selling, as compared to individuals with antecedent drug use.

CHAPTER 2

BACKGROUND AND REVIEW OF THE LITERATURE

2.1 Overview

This chapter sets the stage for this dissertation research project's specific aims and the corresponding research strategy. It also provides background information on the picture of youthful drug selling and the potential importance of drug selling as we use epidemiology to 'make a community diagnosis' and 'complete the epidemiological picture' in research on drug use and drug use disorders. The concepts of 'community diagnosis' and 'completing the picture' are included in Professor Jeremy Morris's influential book and article entitled 'The Uses of Epidemiology,' published more than 50 years ago (Morris, 1964).

The chapter's review of the literature illuminates the estimated prevalence and a traditionally uneven distribution of drug use across sex, gender, and the subgroups that the United States (U.S.) Census labels as 'race-ethnicity.' In the remainder of this dissertation report, the term 'race-ethnicity' is used to be consistent with the U.S. Census. (Of course, the concept of 'race' no longer is a viable scientific construct and has limited utility as we seek to understand the epidemiology of human morbidity and mortality.)

The chapter also covers facets of the etiology of drug selling, which may have links to social and economic contexts (including residence in metropolitan versus other areas of the US), peer affiliations, and familial conditions, including low income, peers who use or sell drugs, living with a single parent, and inept parental supervision. The chapter also covers the evidence on problems associated with drug dealings, such as criminal arrests and violence.

2.2 An Internationally Regulated Drug as an 'Agent' in Epidemiology

The 19th-century founder of modern epidemiology John Snow identified cholera as waterborne. However, it was not clear what the etiology of cholera was until Robert Koch discovered the bacterium *Vibrio cholera*, confirmed a shift of epidemiological research from the miasmatic era to the bacterial era, and established the origins of what we now know designate as epidemiology's 'agent-host-environment' conceptual model.

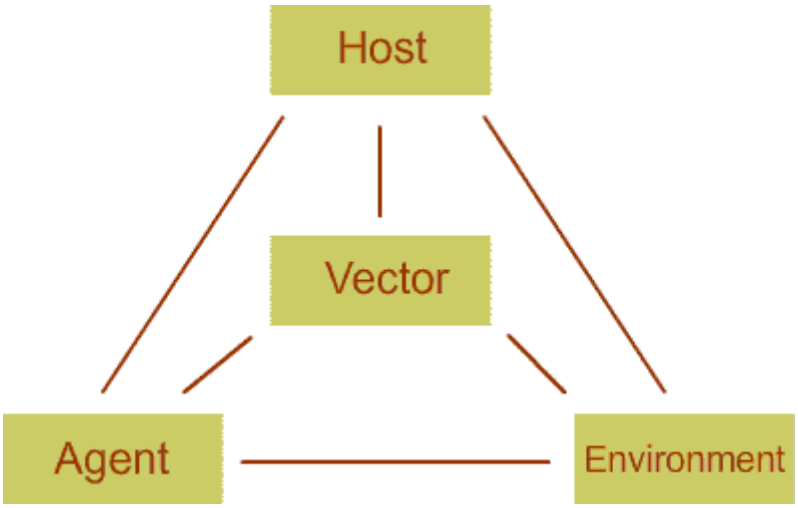

Figure 1. Epidemiologic triad of disease causation.

As we can see from Figure 1, the triad consists of an external agent, a host, and an environment in which host and agent are brought together, with the vector conveying the agent to the susceptible host in a chain of exposures that can result in the occurrence of disease or other responses to occur in the host. The 'vector' transmits infection by conveying the pathogen from its reservoir to susceptible 'hosts' in the human population. In the case of cholera, there is a vehicle in the form of water, but Snow described human vectors who conveyed the Broad Street pump water to London citizens who lived at a distance from the pump and later died from cholera. In the case of Lyme

disease, the vector is a tick. Once effective contact with a pathogen occurs, the interaction between the pathogen and the host in the environment creates a host response. (Gordis, 2014)

In 1983, Anthony applied the concepts of reservoirs and vectors to the study of drug use in human populations. He described how human vectors bring "drug agents" out of their reservoirs and contact potentially susceptible populations. The human vector may be a prescribing physician, a pharmacist who dispenses drugs, a peer who shares drugs as a gift and triggers a new user, or an unregulated seller, such as a street retail "dealer." He noted that epidemiological and public health actions aimed at reducing the risks of drug use might include changes in the regulation of drugs and the behavior of these vectors as conveyers of drugs out of their original reservoirs and who bring the drugs into contact with susceptible hosts. (Anthony 1983)

Anthony was not the first person to analogize drugs transmission to infectious disease and call for the prevention and control of infections agents. As an example, in 1952, a judge in New Jersey wrote the following statement to a drug dealer on the occasion of sentencing him to a lengthy prison sentence ((Livingston, 1963):

“Court for the District of New Jersey in 1952, Judge Forman sentenced one Thaddeus David to term of 2 years and 6 months upon his conviction for violating the Federal narcotic law. The following are excerpts from the Judge’s remarks at the time of sentencing:

You see, Mr. David, you are charged with a very serious offense. What you have done is like carrying diphtheria germs or smallpox germs into the community. Indeed, I think if I had a choice between the two evils, I would rather have a diphtheria epidemic or a smallpox epidemic than I would carries of heroin or narcotics into the community because with diphtheria we find out the source of the germ-it is either bad milk or bad water-----we can vaccinate the people, and we can give them medicine.

Some of them would be victims who would die, others would be cured, and we would clean the neighborhood out. But with carries of this horrible germ, purveyors and peddlers of narcotics, we can't get to the source because people won't tell through fear of some outrageous, perverted sense of what is called "honor" among this class of people. We so often can't get to the source, and we just have this germ going through the community from day to day. "

As with other doctoral dissertations in epidemiology that focus on the agent-host-environment triad for a given disease state or host response, this doctoral dissertation research project is focused on agents (cannabis and other IRD such as cocaine, heroin, crack) and the interactions of a vector (drug dealer) with a vulnerable host.

The epidemiological evidence presented in this dissertation report offers a new perspective on drug sales to adolescents. In many ways, this dissertation provides a preliminary description of the "epidemiology of drug sales" in the 21st century. The dissertation includes a new test of a compelling idea that the odds of drug trafficking may increase in the period after young people first use cannabis or other internationally controlled drugs, relative to the odds of being a drug seller among never users.

In order to provide some background information on the dissertation research project, this chapter covers the following topics. (1) the prevalence of drug sales in the United States; (2) race-ethnicity issues associated with drug sales; (3) sex (male v. female) and age-associated variations in drug selling activity, (4) risk-laden behaviors associated with drug sales; (5) criminal arrests; (6) violence; (7) drug use; (8) related school and psychosocial issues; (9) etiologic influences such as peer and family characteristics; (10) economic conditions, and (11) community characteristics (e.g., non-metropolitan versus metropolitan areas of residence).

The available data cannot be used to make a causal inference. The causal inference must be made by long-term prospective or longitudinal studies, or more optimally, with experimental or quasi-experimental designs that can produce more definitive evidence than a study of this type. However, the dissertation research project offers novel descriptive evidence on the epidemiology of youth drug selling in a U.S. study context and has produced estimates based on recent nationwide surveys that provide the latest information. All estimates can be and have been replicated for the evaluation of reproducibility. I chose age at the time of the assessment (including birth cohort membership as indicated by age), sex (male versus female), and the U.S. Census race-ethnicity subgroupings as covariates of central interest because they would not be influenced by drug selling behavior.

2.3 Prevalence of Drug Sales in the United States

According to the available studies, the prevalence of drug selling can vary appreciably from one time interval to the next and can vary widely depending upon the population sampled for study. To illustrate, an analysis of U.S. drug law violations (Caulkins & Chandler, 2006) shows that adult drug trafficking proportions in both jails and state prisons were maintained around 4-5% from 1977-1982 and then increased over time, particularly in the late 1980s. Among all inmates of jails and state prisons during 1989 and 1991, the estimated proportions of serving time for drug trafficking were 12% and 13.3%, respectively.

Data are not available at a national or state level regarding youth inmates' involvement in drug trafficking. However, with respect to adults, the federal prison drug trafficking proportion increased annually from 42.9% in 1990 to 45.5% in 1997. Saner et al. (1995) analyzed six waves of official

charge data from the Pretrial Services Agency in Washington, D.C., for 1985-1991, showing that the peak in the number of people charged with drug distribution offenses was in 1987.

School-based survey data and community-based survey data from different years and locations can give us an idea of the prevalence of drug trafficking among youth. Two studies (Li et al., 1998; Li & Feigelman, 1994) surveyed youths 9 to 15 years old who resided in or near public housing in Baltimore, MD. The estimated proportions of children involved in drug trafficking were 9% and 7% in 1992 and 1993, respectively. Youths were also asked how likely they thought they would be interested in drug trafficking in the next six months. An estimated 11% of those who had not yet participated and 41% of those with past drug selling predicted they would become involved in selling. Similar epidemiological information was obtained in a school-based survey in D.C. (Altschuler & Brounstein, 1991). These researchers sampled minority boys attending ninth and tenth grade in Washington, D.C., largely from households of poverty. An estimated 13% of the youth reported that they had sold drugs.

Data from the juvenile justice system show larger prevalence proportions for drug dealing in juveniles arrested than in the samples from communities or public schools. In 1991, of 12,235 juvenile arrests in Baltimore, drug-related arrests accounted for 16% of all (Stanton & Galbraith, 1994);these arrests were more about drug selling than drug use. Shook et al. (2011) found that 70% of 227 youthful offenders were selling and/or holding drugs. In the U.S, drug law violations accounted for roughly 11% of all juvenile arrests in 2008 (United States, 2017).

2.4 Age Associated with Drug Sales

As described above, a local area survey of early-mid adolescent low-income youths was conducted by Li & Feigelman (1994). They found a greater proportion of 15 year olds had been drug sellers, with smaller proportions for 12 year olds. Because the sample did not include older adolescents, it did not speak to whether drug selling behaviors might be more common after mid-adolescence.

According to criminal justice samples, there is non-linearity in the age relationships after adolescence. To illustrate, Saner et al. (1995) found that among young adults aged 18-29, those in their early twenties are most often charged for drug distribution and possession. Drug sales offenses seem to be less frequent at older ages than younger ages, among adults aged 18-29.

2.5 Sex and Race-Ethnicity Issues Associated with Drug Sales

The available findings for sex (male and female) tend to show that boys are more likely to sell drugs than girls. For example, in their NSDUH results from 2005-2009, among non-Hispanic Whites, an estimated 4.5% of boys and 2% of girls self-identified as recent drug sellers. The corresponding estimates among Black youths were 6.4% for boys and 1.6% for girls (Floyd et al., 2010). In their local area survey of low-income African-American youths, Li & Feigelman (1994) found an even greater male-female imbalance, with 11% of boys and 1% of girls engaged in drug trafficking.

To date, the topic of gender (e.g., gender identity) has not been addressed in field surveys or criminal justice sample evidence on drug selling. This topic remains a topic for future research.

As for race-ethnicity, some available evidence generally links membership in U.S. Census subgroups with the occurrence of drug selling. This evidence mainly comes from both local area studies and

criminal justice statistics. For example, according to the Baltimore Substance Abuse System data, African American teenagers, who make up about 60% of the youth population, account for 91% of all youth drug arrests in that area, possibly a manifestation of differential policing behaviors even if the occurrence of drug selling did not vary across these subgroups (Stanton & Galbraith, 1994).

Not all evidence is consistent with this generalization. For example, in a sample of juvenile offenders, Shook et al. (2011) found no variation across race-ethnicity subgroups in the prevalence of cannabis and other IRD selling, even though their sample included many more blacks and fewer whites.

Perhaps the most definitive evidence has come from the United States National Surveys on Drug Use and Health (NSDUH). For example, studying more than 13000 NSDUH participants at age 12-17 years, Floyd et al. (2010) found that between 3%-4% had been recent drug sellers, but there was no appreciable variation in these proportions when they contrasted non-Hispanic White youths with non-Hispanic African-American youths (Salas-Wright et al., 2017). Vaughn et al. (2015), with data from the NSDUH, found appreciable variation across race-ethnicity subgroups.

The behavior of community police may be responsible for the impression that Black youths of African-American heritage are over-represented among youths who sell drugs. That is, consistent with evidence on other categories of criminal offending, police may be more likely to apprehend young people 'of color' even when the occurrence of offending does not vary by U.S. Census race-ethnicity subgroups. If so, although subject to self-report limitations, the epidemiological field survey data may provide a more accurate description about this facet of the epidemiology of drug selling.

2.6 Risk-Laden Behaviors Associated with Drug Sales

Youth drug dealing is associated with various risk-laden and criminal behaviors, including the extra-medical use of internationally regulated drugs, alcohol and tobacco products, drug use disorders, getting involved in the juvenile justice system, serious violence, joining gangs, psychosocial adjustment, and school performance difficulties. In this section, I will discuss problems of this type as found to be associated with drug dealing. However, there is no clear causal relationship between these variables.

2.6.1 Drug Use

Among risk-laden behaviors, drug use and the consequences of drug use deserve the most attention because the relationship between the two can help us understand the aspect of "being a vector" in the epidemiology of drug selling. There is considerable evidence to show a cross-sectional association that links becoming a drug user with becoming a drug seller. The rationale often relates to the cost of purchasing drugs and the need to finance one's own drug use. Several of the NSDUH studies cited in previous sections of this chapter have drawn attention to linking drug use to drug selling (e.g., Floyd et al., 2010). More recently, Shook et al. (2013) found that over 80% of drug sellers had used tobacco, alcohol, and marijuana, while in the general population, 19% were tobacco users, 31% were alcohol users, and 13% were marijuana users.

In a survey of 38,399 students attending grades nine through twelve in Franklin County, Ohio, weekly marijuana use was widespread among drug sellers (58.2%), yet relatively few drug sellers (12.2%) were cocaine users (Steinman, 2005). Studying youthful offenders, Shook et al., 2011 found that drug sellers used a wider variety of drugs in the past 12-months than non-drug sellers

Although a clear (possibly non-causal) association between drug dealing and actual drug use has been established, the nature of this relationship remains controversial. An initial theory states that drug use triggers selling behavior (Dunham & Lobos, 2015). The explanation is that drug users make money by selling drugs to maintain their own needs. Hepburn et al. (2016) provided evidence that stimulant drug use (crack cocaine and crystal methamphetamine) was positively and independently associated with the initiation of drug dealing from a longitudinal study. A second theory is that getting involved in drug dealing leads to drug use. For example, peers may encourage the non-drug-using seller to begin using drugs, as suggested by model-based estimates published in a previously cited study (Li & Feigelman, 1994). Adolescents were less likely to engage in drug use if they had not previously been involved in drug use and/or drug trafficking, and adolescents involved in drug trafficking may or may not have previous drug use. In a two year follow up study, there is some evidence that the initiation of drug trafficking by adolescents was sometimes followed by drug use. Of course, initiation of drug use does not necessarily lead to continued involvement in drug-related behaviors (Li et al., 1998). A third theory is that drug use and drug selling are caused by some third factor such as neighborhood conditions or peer associations or living with family members who use drugs and sell drugs (Dunham & Lobos, 2015; Fagan J, 1990).

2.6.2 Criminal Arrest

Drug trafficking has been linked to other criminal activities. One study conducted in 1988 in Washington, D.C. found drug selling was the #1 crime committed by youth to obtain drugs compared to other youths apprehended for crimes such as serious assault, robbery, and burglary (Altschuler & Brounstein, 1991). Drug dealing is a frequent antecedent of juvenile arrests. In a review of drug arrests in Baltimore, it was noted that of the 12,235 juvenile arrests in 1991, 16% were drug-related (Stanton & Galbraith, 1994). More of these arrests were for selling drugs than for using drugs.

From 1986 to 1991, arrests for drug dealing increased substantially while arrests for drug use declined (Stanton & Galbraith, 1994). The volume of drug cases handled by the juvenile court increased by 130% from 1985 to 2018, and the percentage of drug cases as part of the juvenile court's caseload increased from 7% to 14% over the same period (United States, 2017).

A nine-year follow-up study in Vancouver, Canada, pointed out that street-involved youths who sell drugs are more likely to be involved in the criminal justice system, therefore, vulnerable to significant harm associated with it (Hoy et al., 2016). Homelessness, crystal methamphetamine use, and crack-cocaine smoking were identified as correlates of drug dealing initiation among street-involved youth (Hepburn et al., 2016)

2.6.3 Violence

Whether adolescents are actively or passively involved in drug trafficking, once involved, they may become both perpetrators and victims of violence (Rainone et al., 2006; Windle et al., 2020). Many studies have found a relationship between drug selling and violence. The level of violence differed based upon the type of drug being sold ((Deming et al., 2018; Fagan J, 1990; Gordon et al., 2014; Korf et al., 2008; Li & Feigelman, 1994).

The emergence of crack cocaine in the 1980s coincided with a marked increase in violence associated with drug trafficking (Fagan J, 1990). Since then, violence has become tightly related to crack cocaine distribution.

Greater participation in violent crime is not surprising given the realities of the drug market. Dealers have used violence to exert control of markets (e.g., to prevent other traffickers from moving into a neighborhood) and discipline employees (e.g., for thefts). For boys, drug trafficking has been associated with violence-related activities (Li & Feigelman, 1994). Recent studies found that gangs,

drugs, and violence are linked. (Gordon et al., 2014; Korf et al., 2008; Rainone et al., 2006). A study of juvenile offenders in Pittsburgh found that marijuana sellers are more likely to report being engaged in a range of violent and delinquent behaviors and having a gang affiliation than non-sellers (Shook et al., 2011). One might argue that the Pittsburgh study was based on a sample of "high-risk populations" such as those in facilities or with criminal records rather than the "normal population" obtained through school studies. But another study from a random sample of middle and high school students in New York State (Rainone et al., 2006) came to a similar conclusion: the underage and otherwise illegal use of alcohol, marijuana, and other drugs are all strongly associated with violence. Violent behavior in the school-based study was measured by asking students about the number of days they beat up someone, whether they had carried a weapon (knife or gun), and whether they had engaged in gang fights. Early research suggested that committing violent crimes is associated with an increase in an individual's status in gangs, and more recent findings confirmed the critical role of gang affiliation in violent juvenile crimes (see, e.g., Rainone et al., 2006).

There is strong evidence that drug trafficking is associated with homicide. In a 1988 study of murders in New York (Fagan J, 1990), 43% of the murders were found to be related to the drug trade, and another 10% were related to other aspects of drug use. An estimated 29% of the perpetrators and 34% of the victims were involved in the drug trade.

In addition, evidence strongly supports a link between drug dealing and weapon carrying among the youth. Li & Feigelman (1994) found that low-income urban boys involved in drug trafficking and/or use were more likely to carry guns, knives, or other weapons than boys not involved in drugs. Among the boys in the Pittsburgh study (Shook et al., 2011), youths who had been involved in marijuana trafficking were significantly more likely to participate in delinquent behaviors such as carrying a hidden weapon.

2.6.4 Impaired School Performance and Psychosocial Problems

Research on the links between youth drug trafficking, school performance, and psychosocial problems (including mental illnesses) is limited. The studies rarely address temporal sequencing, and they do not produce clear evidence. In some perspectives, drug trafficking is rational after weighing the risk of arrest and potential economic benefits. According to these perspectives, there is no inherent connection between academic or psychosocial problems and drug sales. Some observers regard drug selling as a manifestation of antisocial behavior, which may be accompanied by a decline in academic performance and other social and psychological problems.

As an illustration of the available evidence, in some studies, boys involved in drug selling activities or weapon carrying were more likely to have poor academic performance and school failure than boys who were not involved in the above activities. Shook et al. (2011) studied 227 youthful offenders. They found that compared to non-sellers, the drug sellers, whether they sell marijuana, hard drugs, or prescription drugs, were more likely to have gone to school while drunk or high and to have had sexual intercourse while drinking alcohol or taking drugs. Rainone et al. (2006) did statewide school survey of New York students and showed that 17% of the students reported coming to class high on marijuana at least once during the academic year, while a smaller percentage reported coming to class drunk (13%) or high on a drug other than marijuana (6%). One third of the students (34%) reported that they had skipped school at least once during the school year.

In terms of dropout status, youths who sell drugs are more likely to leave school early. In a nationwide survey of 5373 past-year drug sellers, Vaughn et al. (2015) completed a latent class analysis and found that the lowest occurrence of high school dropout (10.8%) was among the members of 'club drug' users class (e.g., 'ecstasy' users), and the highest occurrence (37.9%) was among the criminal offenders class.

Drug selling behavior has been linked to a range of youth psychosocial issues. For example, some studies have indicated that youths who sell drugs are more likely to experience depression and anxiety. Youths affiliated with gangs often engage in high levels of delinquent behavior, and delinquency among the youth is associated with a range of other problems, including involvement in violence, theft, criminal arrest, and involvement in the juvenile justice system (Fagan J, 1990; Gordon et al., 2014).

In short, drug-related criminal offending and substance use hinder youth's future development. The youth drug sellers can be facing physical and mental health problems and a series of social problems such as impaired school performance, early school dropout, violence, delinquency, and incarceration. These problems, unless prevented, might reduce the chance of successfully transitioning into appropriate adult roles.

2.7 Etiology Associated with Drug Sales

Information about the etiology of youthful drug selling is limited. This literature review disclosed four noteworthy factors that might exert a causal influence. These are drug use, peers, familial factors, and economic factors.

2.7.1 Drug Use

As mentioned in prior sections of this chapter, drug use may trigger selling behavior as drug users could make money by selling drugs to maintain their own needs (Hepburn et al., 2016; Hoy et al., 2016). A nationwide survey of 13706 adolescents aged 12-17 suggested that teenagers who use drugs are more likely to traffic drugs (Floyd et al., 2010). In this study, with cross-sectional analysis and

no time-sequenced approach, the African American/Black youths who used marijuana were an estimated 13 times more likely to sell drugs than peers who had not used marijuana.

Hepburn et al. (2016) completed one of the few longitudinal studies on drug selling and has been able to disentangle temporal sequences in a fashion that has not been possible in the cross-sectional studies cited in prior sections of this chapter. That research provided evidence that stimulant drug use (crack cocaine and crystal methamphetamine) was positively and independently associated with drug dealing initiation, once regression models were used to make covariate adjustments for the following variables: age, gender, race, homeless. Of course, the work requires replication, and important variables may omit from the statistical models that disclosed these relationships. It would be interesting to see evidence supportive of an effect on drug selling onsets in estimates based upon a prevention experiment designed to prevent or disrupt stimulant use.

2.7.2 Peer Influences

Several studies suggest that peers and peer support for selling activity have effects on drug selling. Peer support for selling was considered to be a crucial factor for youth drug tracking in a research report published about 20 years ago (Altschuler & Brounstein, 1991). According to Shook et al. (2011) 's study, all types of drug dealers reported that their friends were more likely to smoke, drink alcohol, and use marijuana compared to non-drug dealers than non-drug dealers. Besides that, they also reported that their friends were more likely to sell drugs. Korf et al.(2008) did international study that studied adolescents between the ages of 14-17 from multiple sites, and found that most of the participants sold drugs to friends or acquaintances.

Can we say that resistance to peer influence reduces deviance in one's own behavior? The answer is no. Little & Steinberg’s (2006) research indicated that adolescents with high resistance to peer

influence actually might be at an increased risk of engaging in drug dealing behaviors. This study measured an adolescent's ability to make decisions alone without peer social influence using a 20-item self-report measure. A total score was calculated based on their responses. The results showed that adolescents' resistance to peer influence positively affected their drug dealing, especially for non-marijuana drugs, which is understandable as dealing non-marijuana drugs requires adolescents to be more independent, tolerate high risk, and know how to manage the client base. Teens whose peers do not influence may have the above abilities or talents to succeed as drug dealers. Wojciechowski's (2020) longitudinal study followed 1354 juvenile offenders for 84 months from adolescence to early adulthood and found that adolescents reporting higher resistance levels to peer influence sold drugs more frequently. This set of findings is somewhat perplexing. It is raises an issue that cannot be addressed in this dissertation research project work, but it represents an interesting area for future research that might be addressed with more detailed investigation.

Steinman (2005) concluded with a challenge to the popular view of adult drug dealers or out-of-school youth being the primary source of these drugs: "selling drugs is not limited to a few troubled schoolers. Many high school students simply look for "drug dealers" in their classrooms."

2.7.3 Familial Factors

Wojciechowski (2020) conducted a longitudinal study to examine the degree of parents monitoring child behavior. The theory is that children monitored closely by their parents have fewer opportunities for engagement in drug dealing. Lower levels of parental monitoring at baseline predicted increased risk of marijuana dealing behavior later. This result is consistent with an empirical finding that youths with less parental supervision have more time and chance to plan and sell drugs and maintain a client base (Little & Steinberg, 2006). In addition to parental supervision, poor communication between parents and adolescents also seems related to drug selling.

The Little and Steinberg study (Little & Steinberg, 2006) also found that adolescents who were exposed to parental alcohol or other drug use and abuse were more likely to have access to drug use and get involved in drug selling. In a survey of youthful offenders (Shook et al., 2011), participants were asked "whether a household member (yes/no) or family member sold drugs(yes/no)," and the results showed that marijuana and hard drug sellers were more likely to have a household or family member who sold drugs than non-sellers.

2.7.4 Economic Factors and Perception

Several studies indicate that income could motivate drug dealing, including the previously cited Li & Feigelman (1994) study of 351 African American youths 11-15 years old. Their analysis supported the theory that economic motivation is an important factor associated with boys' involvement in drug trafficking. Boys with drug dealing experience expressed a view that "selling is the main way kids make money."

With data from an urban sample of 605 serious male juvenile offenders, Little & Steinberg (2006) found that the young people in the sample made considerable income from drug selling (e.g., $1,692.67/week), which was substantially greater than the average weekly income in the regular job market (e.g., $44.88/week). However, Wojciechowski's (2020) longitudinal study did not provide support along these lines. His study did not find an association between participants' perceptions of available legal job opportunities at baseline in their neighborhood with drug selling in any study group. Nevertheless, Li & Feigelman (1994) found that youths with perceptions that neighbors, friends, or family members are involved in drug trafficking seem to be more likely to engage in drug trafficking themselves.

2.8 Summary

This literature review covers a variety of factors across a range of behavioral and social science theories that invoke linkages to drug selling. The review illuminates an issue raised in Chapter 1 of the dissertation research report. Namely, few investigations have been guided by the idea that the epidemiological triad of agent-host-environment and the vector concept might be useful when we try to think through future public health interventions to reduce the occurrence of adolescent drug use.

The review discloses that we know little about the role of young people as vectors who convey a drug 'agent' out of a reservoir and bring the agent into contact with susceptible hosts in the community environment. In this line of research work, it should be possible to hypothesize a process or set of pathways of drug involvement that includes, but is not limited to, young people being approached by someone selling drugs, starting their first drug use, having a drug dependency syndrome, and then using drug dealing with sustaining their supplies of drugs, with new dealers restarting this pathway resulting in more young drug dealers. However, in-depth, comprehensive research on this topic has not yet been completed. Most of the evidence is based on cross-sectional survey evidence from the local areas under study, and some of the nationwide surveys are out of date. No more than a handful of longitudinal studies have been completed, and there has been no systematic attempt to replicate the findings.

This study cannot fill all the previously mentioned gaps or be used to make a causal inference. However, for the first time, this dissertation research project pay attention to temporal sequencing of data gathered in cross-sectional surveys with epidemiologically credible samples of young people in the United States during the 21st century, including data gathered as recently as December 2019.

If successful, the research described in this dissertation research project will lay a foundation of evidence that can be used to guide future epidemiological investigations of youth drug selling. It should promote thinking about public health interventions that seek to disrupt the occurrence of youthful drug use by directing attention to the epidemiological patterns of youthful drug selling. As such, the dissertation research project and its epidemiological evidence may help create conditions for future longitudinal research projects.

My intent in Chapter 2 has been to summarize the published evidence on youthful drug selling and to help motivate how an epidemiological approach to research on youthful drug selling might provide guidance for future public health interventions designed to reduce and prevent occurrence of youthful drug use. At this stage of the research, the aims of the project are deliberately constrained because, to this point, we do not know much about basic epidemiological parameter estimates such as the age-specific, cohort-specific, and sex-specific variations in the occurrence of youthful drug selling. This project will not answer questions about causal relationships that are going to become more important as we study drug selling of 'vectors' as an epidemiological phenomenon. Rather, it will lay a foundation of evidence that can be used to guide future epidemiological studies, either longitudinal and prospective studies or experiments and quasi-experiments designed to produce definitive evidence. Fulfillment of the dissertation research project aims will represent steps forward in this type of progress toward increasingly definitive evidence.

CHAPTER 3

METHODS

3.1 Overview

This chapter describes the study populations, the sampling procedure, the survey assessment, and the methods issued to test the study's hypotheses. For this dissertation, the data I used were drawn from the United States National Surveys on Drug Use and Health (NSDUH) conducted each year from 2005 through 2019. The NSDUH has been conducted annually during that interval with roughly 70,000 participants in each year's independently drawn sample. The survey provides the U.S. with the latest information on the use of cannabis and other internationally regulated drugs, mental health, and other health-related problems as experienced by non-institutionalized civilian resident populations of the United States in recent years. The federal government commissioned the completion of the NSDUH surveys and has provided detailed methodological reports each year (e.g., Substance Abuse and Mental Health Services Administration, 2021).

I draw attention to the dissertation research project's focus on prevalence proportions estimated via a series of newly drawn annual cross-sectional national probability sample surveys. It can be argued that a prospective study design, enrolling drug-free youths at baseline and following them up, would be more appropriate than the cross-sectional study design for investing the relationship between drug use and drug dealing problems. However, the classical study from Wade Hampton Frost using repeated cross-sectional death data (FROST, 1939) presented an epidemiological mutoscope view of the 1880 birth cohort's trajectory of tuberculosis death rates in comparison with other birth cohorts. The useful view cohort development can be constructed by using statistical estimates such

as age-year-specific prevalence proportions or rates from repeated cross-sectional panel surveys, as initially described by Seedall & Anthony (2015) and characterized as a ‘mutoscope’ view of each birth cohort’s experience as time passes. Once a ‘mutoscope’ table is formed, each cohort’s snapshot estimates along the (sub-)diagonal of the table provide a dynamic view of the cohort’s development. For this reason, this dissertation’s cross-sectionally derived estimates of drug-selling activities also shed light on the age-specific incidence of drug selling.

3.2 Main Hypotheses

The main aims are already presented in Chapter 1. I examined the following specific hypotheses pertaining to the main aims:

- The relationship between youth demographic information (age, sex (male versus female), race-ethnicity) and drug selling behavior.

I. As the age increases, the likelihood of selling drugs increases in male youths.

II. There is a monotonically increase for age-specific prevalence.

- Transform age-and-year specific prevalence estimates to birth-cohort-and-age specific estimates and examine the cohort effect on the prevalence.

I. The prevalence of participation in drug selling would be lower for younger cohorts.

II. The drug-selling prevalence reaches the peak at age 17.

III. There has been a declining trend of drug selling over the years 2005-2019.

- Influence of elapsed time since the onset of IRD use and type of IRD drug at first use on drug selling behavior.

I. The odds of drug selling after the first use of non-cannabis IRD compounds differ from the post-cannabis odds of drug selling.

II. The odds of being a recent drug seller varies with the elapsed time since the onset of IRD use.

3.3 Sampling Procedure

The Substance Abuse and Mental Health Services Administration (SAMHSA) has conducted NSDUH every year since 1971. They began in 1999 and continued through subsequent years. The surveys are conducted using computer-assisted interviewing (CAI) methods. Participants were given a $30 incentive for doing this survey since 2002. The incentive had increased response rates for a while; however, response rates have been declining recently. When response rates drop, more households would be selected to make sure an adequate sample size. The surveyed people varied year to year, with the annual number ranging from roughly 65,000 to 70,000.

Despite the survey questions and variables changing over the year, the basic sampling procedure and data collection remain the same. Data have been collected from all 50 states and the District of Columbia to ensure the sample represents the entire U.S. population. NSDUH uses a multistage area

probability design, meaning that larger geographic areas are broken down into sequentially smaller areas before the final sample dwelling units have been reached. Using the information from U.S. Census Bureau, each state of the U.S. is divided into state sampling regions (SSRs) in the first stage, and the population size of each state decides the number of SSRs. The selected SSRs are then divided into segments in the second stage. In each SSR, eight segments were selected. Next, dwelling units (DU) are listed within each selected segment, and some of the dwellings are selected in the third stage. These selected units are called sample dwelling units (SDUs). All above clusters are chosen at random at each stage.

Once the specific households have been selected, a trained interviewer will go to the SDU. The interviewer would ask to speak with a household resident who is over the age of 18, then do a short screening interview using a laptop to determine if the SDU was eligible to participate in the NSDUH. The interviewer would create a list of all people who lived in the unit most of the time and their basic demographic information. The computer uses the demographic data in a pre-determined algorithm to select 0, 1, and 2 individuals to be interviewed. The selection process does not consider the relationship between family members. Adolescents aged 12 to 17 years and young adults aged 18 to 25 years were oversampled compared to their proportions in the population to generate more accurate estimates for these age groups.

Immediately after completion of the screening, the interviewer attempts to conduct NSDUH interviews with the selected individuals. Because the interviews involved illicit drug use and more sensitive behavioral issues, the interviewer would ask the interviewee to interview for approximately one hour in a private area of the home, away from other family members. Now, audio computer-assisted self-interviewing (ACASI) has been adopted in the NSDUH data collection process to encourage respondents to provide accurate information by providing a highly private and

confidential mode. In the ACASI approach, a laptop or tablet would be provided to participants, and they only need to wear headphones to listen to the self-interview questions and then enter their answers, with no interviewer involved in this process. The interviewers have been replaced by staff members whose role is coming to the dwelling unit with a laptop or tablet, securing informed consent, and teaching surveyors about how to use the ACASI apparatus.

3.4 Population Under Study and Study Sample

After Institutional Review Board-approved consent procedures, all participants are assessed using confidential audio computer-assisted self-interview. Participation levels for designated respondents declined over the years since 2002 but have stabilized somewhat at roughly 65%-70%.

From 2005-2019, NSDUH surveyed 840,510 non-institutionalized US civilian residents aged 12 years and older in all 50 states and the District of Columbia. The study population focus on 12-to-17-year-old adolescents, the unweighted total number of adolescents from all the survey samples, is 243,283. Unweighted numbers of designated 12–17-year-old participants in each year's multi-stage area probability sample range from 13,287 to 19,264. Although the number of participants in this age group does not decline linearly, the overall trend is down. The most apparent decline happened from the Year 2013 to the Year 2014. Among the 243,283 youths from 2005-2019, 51% were male. The majority were non-Hispanic White (56.92%) or Hispanic (21.54%), and the remainder were African American, Asian, Native American, etc. 7200 (2.66%) of 243,283 youth reported having sold illegal drugs once or more in the past year. The participants with missing or invalid responses to key study variables such as drug selling in the past year were removed.

3.5 Variables

3.5.1 Response Variable-Recent Drug Selling

After Institutional Review Board-approved consent procedures, all participants are assessed using confidential audio computer-assisted self-interview. Participants were assessed via youth experience modules. This section covered youth school activities, behaviors, peers/parents' attitudes for substance use, and so on. The question used to generate the response variable was:

a. During the past 12 months, how many times have you sold illegal drugs?

1 0 times

2 1 or 2 times

3 3 to 5 times

4 6 to 9 times

5 10 or more times

I dichotomize the answer into 0 times and 1+ times.

3.5.2 Age of First Substance Use

One purpose of this study is to capture time effects. I want to know if the odds of recent drug selling may vary for the elapsed time since the onset of IRD use. According to each substance use module of the survey, participants were asked if they ever, even once, used any form of the listed substances. If they said "yes," they would be asked the age of first-time use. The questions were as follows:

a. Have you ever, even once, used cannabis or hashish?

1 Yes

2 No

If the answer was yes, the next question is

How old were you the first time you used cannabis or hashish? AGE: [RANGE: 1 - 110]

b. Please think again about answering this question: Have you ever, even once, used any form of cocaine?

1 Yes

2 No

How old were you the first time you used cocaine, in any form? AGE: [RANGE: 1 - 110]

c. Please think again about answering this question: Have you ever, even once, used ‘crack’?

1 Yes

2 No

How old were you the first time you used ‘crack’? AGE: [RANGE: 1 - 110]

d. Please think again about answering this question: Have you ever, even once, used heroin?

1 Yes

2 No

How old were you the first time you used heroin? AGE: [RANGE: 1 - 110]

e. Please think again about answering this question: Have you ever, even once, used LSD, also called ‘acid’?

1 Yes

2 No

Have you ever, even once, used PCP, also called ‘angel dust’ or phencyclidine?

1 Yes

2 No

How old were you the first time you used [LSFILL]? AGE: [RANGE: 1 - 110]

3.5.3 Recency of Cannabis and Other Internationally Regulated Drugs Used Extra-Medically

a. How long has it been since you last used cannabis or hashish?

1 = Within the past 30 days

2 = More than 30 days ago but within the past 12 mos

3 = More than 12 months ago

9 = NEVER USED CANNABIS

b. How long has it been since you last used cocaine?

1 = Within the past 30 days

2 = More than 30 days ago but within the past 12 mos

3 = More than 12 months ago

9 = NEVER USED COCAINE

c. How long has it been since you last used use 'crack'?

1 = Within the past 30 days

2 = More than 30 days ago but within the past 12 mos

3 = More than 12 months ago

9 = NEVER USED CRACK

d. How long has it been since you last used heroin?

1 = Within the past 30 days

2 = More than 30 days ago but within the past 12 mos

3 = More than 12 months ago

9 = NEVER USED HEROIN

e. How long has it been since you last used LSD?

1 = Within the past 30 days

2 = More than 30 days ago but within the past 12 mos

3 = More than 12 months ago

9 = NEVER USED LSD

f. How long has it been since you last used PCP?

1 = Within the past 30 days

2 = More than 30 days ago but within the past 12 mos

3 = More than 12 months ago

9 = NEVER USED PCP

3.5.4 Other Covariates

Besides demographic information such as gender, race, age, county type, the other covariates include family income, school enrollment, father in the household, substance use in the past year (cannabis, alcohol, tobacco. etc.).

3.6 Data Coding and Preparation

The data of this study include self-reported recent drug selling behavior as the main outcome. The key covariates include self-reported IRD use, age at first-time IRD use, as well as covariates of social-economic characteristics. The coding of the outcome and the covariates is as follows.

Past-year drug selling: This variable was coded as having sold illegal drugs once or more (1) or having not sold illegal drugs (0) in the past year.

Sex: 1: male, 2: female

Age: Range= (12 – 99) in the survey, I only select 12-17

Race: Due to the relatively small number of participants, the racial groups of Non-Hispanic Native Am/AK Native, Non-Hispanic Native HI/Other Pacific Island, and Non-Hispanic Asian were

combined into one called “other.” Without the combination, their low rates of drug selling would generate unstable estimates. The race was coded as 1: white, 2: black, 3: Hispanic, and 4:other.

Elapsed time: Difference between age at survey and age at first IRD use. I have a list of IRD drugs which include cannabis, crack, cocaine, heroin, LSD, and PCP. Based on survey questions, I could select the minimal age at the use of any above IRD as age at first IRD.

Birth year: Survey year-age

Type of IRD first used: Group the type of IRD at first use into cannabis only vs. non-cannabis drugs with or without concurrent cannabis use. If the youth starts with cannabis only, he/she would be assigned to the cannabis-only group. If he/she starts with other drugs or simultaneously uses cannabis and other drugs, the youth would be assigned to the group of non-cannabis drugs with or without concurrent cannabis use.

Age at first IRD use: The survey includes the age of first use of each substance. I selected the minimum age as the first IRD age.

Initiating IRD use with only cannabis in 12-24 months before the interview quarter: 1=the participant started IRD use with only cannabis in 12-24 months before the first day of the interview 0=never use IRD. This variable is only defined in these two groups of participants.

County type: 1=Large Metro(pop>=1 million); 2=Small Metro (pop<250,000 and pop 250,000-1,000,000); 3=Nonmetro (Rural or urban pop 2,500-20,000).

Family Income: 1 - Less than $20,000; 2 - $20,000 - $49,999 ; 3 - $50,000 - $74,999 ; 4 - $75,000 or More.

Past year substance use: 0=have not used any substance in the past year; 1=have used only cannabis in the past year; 2=have used at least one non-cannabis drug.

3.7 Analytic Plan

In this study, the mutoscope approaches, meta-analysis, and logistic regression for complex survey data were utilized to analyze the NSDUH data. For statistical inference, the methods used in this study account for the design features of the NSDUH, including stratification, clustering, and weighting.

3.7.1 Exploratory Data Analysis

Exploratory data analysis was used to show the frequency and distribution of drug selling, demographic information, and key covariates. Results are displayed in both tables and plots. Annual prevalence estimates will be calculated for each age among the full sample and by racial/ethnic and gender subgroups. Association between drug selling and other key variables were examined by Rao-Scott chi-square test using the stratification and clustering, weighting information in the survey.

3.7.2 Epidemiological Mutoscope View

In 1937, the father of modern epidemiology, Wade Hampton Frost, did a classical study to find an answer to the question that “Does the rate of death from tuberculosis increase with age?”(Comstock, 2001). Frost cross-tabulated tuberculosis mortality rates by year and age group and highlighted those rates of the cohort of people born during the same decade (Table 1). he found that the tuberculosis mortality rate was high in infancy but consistently decreased after 30 years of age. The pattern of tuberculosis mortality rate over age was very similar for all the birth cohorts (FROST, 1939)The

approach that Wade Hampton Frost used to study the age-specific tuberculosis mortality rates of a cohort from the rates of samples of different age-collection-year combinations has been called a "mutoscope approach" because it displays 'motion' of each birth cohort under study via a sequence of cross-sectional snapshots, as explained by others (Cheng et al., 2016; Seedall & Anthony, 2015) When the contingency table is applied to a series of cross-sectional survey data, the (sub-)diagonal view of this table holds a constant cohort, which provides a view of each cohort's experience.

In this study, I will first calculate the prevalence of recent drug selling behaviors by age (from 12 to 17) and survey year, and then transform age-and-year specific prevalence estimates to birth-cohort-and-age specific estimates by a mutoscope view. Once the table of prevalences by age and year was formed, I can study the trajectory of the prevalence of recent drug selling for each birth cohort over age, with new samples drawn year by year (but no repeated measures of the same individuals).

Table 1. Table 1 in Frost (1995)

TABLE 1

*Death rates * per 100,000 from tuberculosis, all forms, for Massachusetts, 1880 to 1930, by age and sex, with rates for cohort of 1880 indicated*

Age	1880	1890	1900	1910	1920	1930
Males						
0– 4	760	578	309	209	108	41
5– 9	43	49	31	21	24	11
10–19	126	115	90	63	49	21
20–29	444	361	288	207	149	81
30–39	378	368	296	253	164	115
40–49	364	336	253	253	175	118
50–59	366	325	267	252	171	127
60–69	475	346	304	246	172	95
70+	672	396	343	163	127	95
Females						
0– 4	658	595	354	162	101	27
5– 9	71	82	49	45	24	13
10–19	265	213	145	92	78	37
20–29	537	393	290	207	167	92
30–39	422	372	260	189	135	73
40–49	307	307	211	153	108	53
50–59	334	234	173	130	83	47
60–69	434	295	172	118	83	56
70+	584	375	296	126	68	40

* They were obtained as follows: For the years 1910, 1920 and 1930—based on U. S. Mortality Statistics—deaths from tuberculosis, all forms. For the years 1880, 1890 and 1900 the rates used are calculated from data compiled by the late Dr. Edgar Sydenstricker from the state records. Because of differences of classification in deaths, it has been necessary to base the rates on the deaths recorded as "tuberculosis of the lungs" to get comparable data for these years. The rate calculated from the state records for "tuberculosis of the lungs" has been multiplited by a factor based on the proportion such deaths bore to those from tuberculosis, all forms. This factor varied with the year and age considered.

3.7.3 Logistic Regression for Complex Survey Data

The logistic regression model is a special case of the generalized linear model, which is often used to investigate the relationship between a dichotomous response Y (e.g., sold drug $Y=1$ or not $Y=0$) and a set of explanatory variables $\mathbf{x}$. The logistic regression uses the logit link function, and the model has the form:

$$\text{logit}(p(\mathbf{x})) = \log\left(\frac{p(\mathbf{x})}{1-p(\mathbf{x})}\right) = \alpha + \mathbf{x}'\beta$$

where $p(\mathbf{x}) = P[Y=1 \mid \mathbf{x}]$ is the probability that the event of interest occurs, $p(\mathbf{x})/(1- p(\mathbf{x}))$ is the odds, α is the intercept parameter, β is the vector of slope (regression) parameters, and $\mathbf{x}$ is a vector of explanatory variables.

Logistic regression for complex survey data is a special type of logistic regression to adjust for the design features of the survey, including, e.g., stratification, clustering, and unequal sampling probabilities (Heeringa et al., 2017). The design variables are available in the data set of each year's NSDUH. I used the SAS procedure PROC SURVEYLOGISTIC to perform logistic regression for complex survey data in this study. The outcome variable for all the logistic regression models in this study is whether the adolescent sold drugs, coded $Y=1$, in the 12 months prior to the interview.

For Aim 3, I applied PROC SURVEYLOGISTIC to the data of each of the 15 surveys. The covariates of each logistic regression model include ever use of drugs, drug type at first use, the elapsed time from first drug use to interview, the interaction between drug type and elapsed time, age at interview, sex, and race, where elapsed time is treated as a categorical covariate with values 0 yrs, 1 yrs, 2 yrs, 3 yrs, and 4+ yrs.

For Aim 4, I also applied PROC SURVEYLOGISTIC to the data of each of the 15 surveys. There are two types of logistic regression models for this aim. I first fit models with only one covariate named prior cannabis use to generate crude odds ratios. Priori cannabis use indicates whether the subject has never used any drug or started IRD use with only cannabis in 12-24 months before the first day of the quarter in which the interview was conducted. The crude odds ratio shows the strength of association between the initiation of cannabis use and drug selling in the next year. The other logistic regression model has additional covariates of age at interview, sex, and race/ethnicity., i.e., adjusting for potential confounders.

All the statistical tests are two-sided with a significance level of 0.05. Consistent with recent expressions of concern about the concept of statistical significance and a proposal to move from hypothesis-testing to interval estimation (e.g., Greenland et al., 2016), I have presented 95% confidence intervals for the estimates in this dissertation project report. In addition, I have provided p-values for readers who prefer to take the hypothesis-testing approach. I have avoided use of the term ‘statistical significance’ and ‘significance’ or ‘significant association’ for the reasons explained in the article by Greenland and colleagues. As an alternative, any estimates for which p-value<0.05 is described as “robust” or “robust and precise”.

3.7.4 Meta-Analysis

Meta-analysis is a statistical analysis that usually be used to simultaneously estimate treatment effects across many clinicals conducted by different research team and various location. In my research, I have 15 independent assessments addressing same questions, with each individual survey reporting measurements that are expected to have some degree of error. Outcomes from a meta-analysis may include a more precise estimate of the effect of drug selling, than any individual study

contributing to the pooled analysis. The examination of variability or heterogeneity in study results is also a critical outcome which can tell us if there is variation across the years (Luntz, 1944).

For Aim 2, I performed a meta-analysis of the prevalence of recent drug selling for each age. The meta-analysis starts with estimating prevalence of recent drug selling by year and age. The prevalence estimates are used to form the mutoscope table. The variances of the age-year-specific prevalence estimators are calculated. Because each year's survey was conducted independently, the prevalence and variance estimates of all the years are used as the input data for the meta-analysis. Then meta-analytic summary estimates of prevalence at each age are generated using DerSimonian and Laird's random effects approach (DerSimonian & Laird, 1986). I use a SAS macro %METAANAL to implement that approach. Besides providing the summary estimates, it can test for the significance of the average prevalence and the between-survey heterogeneity. There is new SAS procedure named BGLIMM based on Bayesian methods have been developed recently can also be used for meta-analysis (Rott et al., 2021).

For Aim 3 and 4, I first applied PROC SURVEYLOGISTIC to the data of each of the 15 surveys and then performed a meta-analysis of the 15 sets of effect estimates using DerSimonian and Laird's random effects approach (DerSimonian & Laird, 1986).

CHAPTER 4

RESULTS

4.1 Results for Aim 1

4.1.1 Overview

This chapter presents sociodemographic factors of interest in relation to the occurrence of drug selling behavior, trends, and prevalence of drug selling among youth. The results were summarized first by sample characteristics, followed by the distribution of sociodemographic factors. The association between variables of interest and drug selling behaviors was investigated using the Rao-Scott chi-square test and survey logistic regression. Last, trends of youth drug selling from 2005-2019 and age-specific prevalence of recent drug selling behaviors by age from 12 to 17 years and the following subgroups were presented by plots.

4.1.2 Sample Characteristics

There are 243,283 noninstitutionalized youth aged 12-17 participating National Survey on Drug Use and Health (NSDUH) from 2005-2019,7200 (2.66%) of them reported having sold illegal drugs once or more in the past 12 months. The proposed study aims to use birth-cohort-and-age-specific drug selling prevalence to construct a mutoscope view and focuses on the estimation of how elapsed time since the onset of internationally regulated drug (IRD) use and prior marijuana use influence recent drug selling.

The distribution of socio-demographic characteristics for those 7,200 youths is presented in Table 2 of the 7,200 participants. More than twice as many boys (69.9%) as girls (30.1%) were involved in

selling drugs. Most participants are non-Hispanic White adolescents (58%) or Hispanic adolescents (21%). The mean age of youths who sold drugs is 15.7 years. More than half of youth drug sellers came from large metro areas where the population is above 100,000.

Table 2 also presents the distribution of key variables, including family's income, peer's cannabis use, gun carried in school, fight with one parent, serious fight at school, average grade. Among those social factors, the distribution of peer's cannabis use, gun carried in school, the youth had a serious fight at school differs very much between drug seller and non-drug seller groups. Of youth who involved in drug selling, 71% youth reported most/all the students in their grade at school use cannabis or hashish; among youth who did not involve in drug selling, 75% youth believe few/none of the students in their grade at school use cannabis or hashish. Youth who sold drugs are more likely to have a serious fight one or more times at school (53.3% versus 18.1%), to carry a handgun one or more times (31% vs 3%) than youth who did not sell drugs. Youth who did not sell drugs also have better school performance. 77.8% of them get an average grade B or above, but only 49.1% of youth get an average grade B or above when they are involved in selling drugs. The distributions of family income values, fighting with a parent in the past year, and county metro/nonmetro status show relatively smaller variations as compared with the already mentioned social factors studied for recent drug sellers versus non-sellers.

Table 2. Drug seller and non-drug seller by sociodemographic factors-NSDUH 2005-2019.

	Non-drug seller	**Drug seller**
	(n=236,083)	**(n=7,200)**
Continuous Variables, Mean (STDERR)		
Age (years)	14.52 (.005)	15.70 (.019)
Categorical Variables, N (%)		
Sex		
Girls	118,892(50.42)	2,197(30.10)
Boys	117,191(49.57)	5,003(69.90)
Race/ethnicity		
White	134,566(55.92)	4,094(58.20)
Hispanic	457,15(21.41)	1,365(21.04)
black	31,886(14.28)	980(14.05)
Asian	8,292(4.84)	88(1.66)
others	15,624(3.56)	673(5.04)
Annual Family Income		
1 - Less than $20,000	40,146(16.42)	1,416(18.94)
2 - $20,000 - $49,999	73,021(29.73)	2,454(32.83)
3 - $50,000 - $74,999	41,140(16.44)	1,224(15.45)
4 - $75,000 or More	81,776(37.41)	2,106(32.79)
Peer's cannabis use		
1 - None of them	62,726(29.60)	189(2.77)
2 - Few of them	96,668(45.44)	1,766(26.25)
3 - Most of them	49,420(23.49)	4,137(62.15)
4 - All of them	3,220(1.47)	618(8.83)
Average Grade		
1 - An A+, A or A-minus average	70,127(33.12)	847(13.10)
2 - A B+ , B or B-minus average	88,093(40.74)	2,318(36.04)
3 - A C+ , C or C-minus average	41,824(18.26)	2,213(32.24)
4 - A D or less than a D average	10,971(4.71)	1,147(16.08)
5 - My school does not give these grades	68,89(3.19)	150(2.54)
Fight with a parent in past year		
1 - 0 times	43,268(19.20)	613(8.59)
2 - 1 or 2 times	66,177(28.55)	1,528(21.64)
3 - 3 to 5 times	49,621(21.21)	1,381(19.05)

Table 2 (cont'd)

4 - 6 to 9 times	24,823(10.60)	989(13.58)
5 - 10 or more times	49,028(20.45)	2,647(37.15)
Youth had a serious fight at school		
1 - 0 times	190,814(81.89)	3,316(46.89)
2 - 1 or 2 times	34,879(14.28)	2,312(32.08)
3 - 3 to 5 times	6,542(2.64)	868(11.82)
4 - 6 to 9 times	1,520(0.60)	327(4.58)
5 - 10 or more times	1,515(0.60)	349(4.63)
Carried a Handgun		
1 - 0 times	227,922(97.02)	4,964(68.97)
2 - 1 or 2 times	5,174(2.05)	1,267(17.72)
3 - 3 to 5 times	1,228(0.47)	386(5.61)
4 - 6 to 9 times	400(0.14)	202(2.61)
5 - 10 or more times	901(0.31)	369(5.10)
County Metro/Nonmetro Status		
1 - Large Metro	10,5107(54.86)	3,147(53.72)
2 - Small Metro	80,444(29.77)	2,569(32.01)
3 - Nonmetro	50,532(15.37)	1,484(14.26)

Table 3 presents the distribution of recency illegal drug use among sellers and non-sellers. Recency illegal drug use included cannabis, cocaine, crack, heroin, LSD, and PCP. Compared to non-drug sellers, the drug sellers have higher rates of drug use in terms of all the listed illegal drugs. Of the 7,200 youth drug seller, 5,905 (81.44%) had used cannabis within the past 12 months. Among youth who did not sell drugs, the rate of cannabis use in the past 12 months is 11.21%. Although cannabis use in non-drug sellers is robust lower than drug sellers, cannabis is the most popular drug for all adolescents than other drugs. After cannabis, Cocaine and LSD are the second and third popular drugs for youth drug dealers. 1,037 (14.8%) participants reported having used cocaine within the past 12 months. 791 (10.9%) participants reported having used LSD within the past 12 months. Of

236,083 non-drug sellers, over 99% of adolescents never used cocaine, crack, heroin, LSD, and PCP. The three most popular drugs are the same in both drug seller and non-drug seller groups.

Table 3. Drug seller and non-drug seller by recency illegal drug use -NSDUH 2005-2019.

	Non-drug seller (n=236,083)	Drug seller (n=7,200)
Categorical Variables, N (%)		
Cannabis		
1 - Within the past 12 months	27,856(11.21)	5,905(81.44)
2 -More than 12 months ago	8,028(3.21)	421(5.76)
9 - Never used cannabis	200,199(85.58)	874(12.80)
Cocaine		
1 - Within the past 12 months	1,229(0.51)	1,037(14.87)
2 -More than 12 months ago	7,24(0.27)	370(5.04)
9 - Never used cocaine	234,130(99.22)	5,793(80.09)
Crack		
1 - Within the past 12 months	126(0.04)	164(1.95)
2 -More than 12 months ago	176(0.07)	122(1.59)
9 - Never used crack	235,781(99.89)	6,914(96.45)
Heroin		
1 - Within the past 12 months	127(0.05)	153(2.13)
2 -More than 12 months ago	130(0.04)	102(1.38)
9 - Never used heroin	235,826(99.91)	6,945(96.49)
LSD		
1 - Within the past 12 months	1,016(0.43)	791(10.94)
2 -More than 12 months ago	696(0.28)	343(4.46)
9 - Never used LSD	234,371(99.30)	6,066(94.75)
PCP		
1 - Within the past 12 months	210(0.08)	207(2.78)
2 - More than 12 months ago	284(0.10)	196(2.47)
9 - Never used PCP	235,589(99.83)	6,797(96.45)

4.1.3 Trends of Drug Selling Among Youth from 2005-2019

As shown in Figure 2, in the study period from 2005 through 2019, the prevalence of drug selling of youth aged 12-17 varied from 2% to 3.3%. The prevalence of youth selling drugs dropped from 2006 to 2007 and then increased from 2007 to 2009. After that, there was an obvious decrease from 2009

to 2014. 2014 was a turning point. Since 2014, the prevalence has been going up and down, but the overall trend is decreasing.

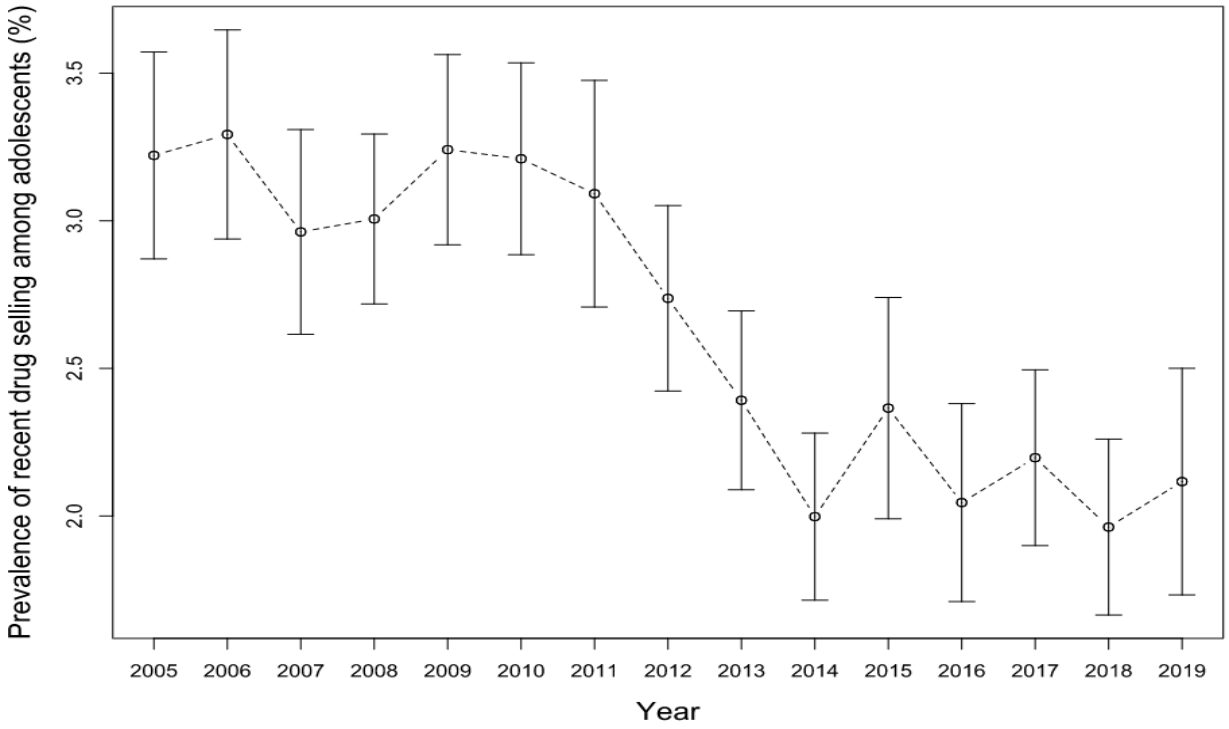

Figure 2. Prevalence of drug selling during 2005-2019 among adolescents 12-17 years old.

4.1.4 Age-Specific Prevalence of Drug Selling

As shown in Figure 2, the age-specific prevalence increased as age increased. Older youths are more likely to sell drugs. Boys were more likely to sell drugs than girls at any age. This sex difference has gotten bigger and bigger since age 13.

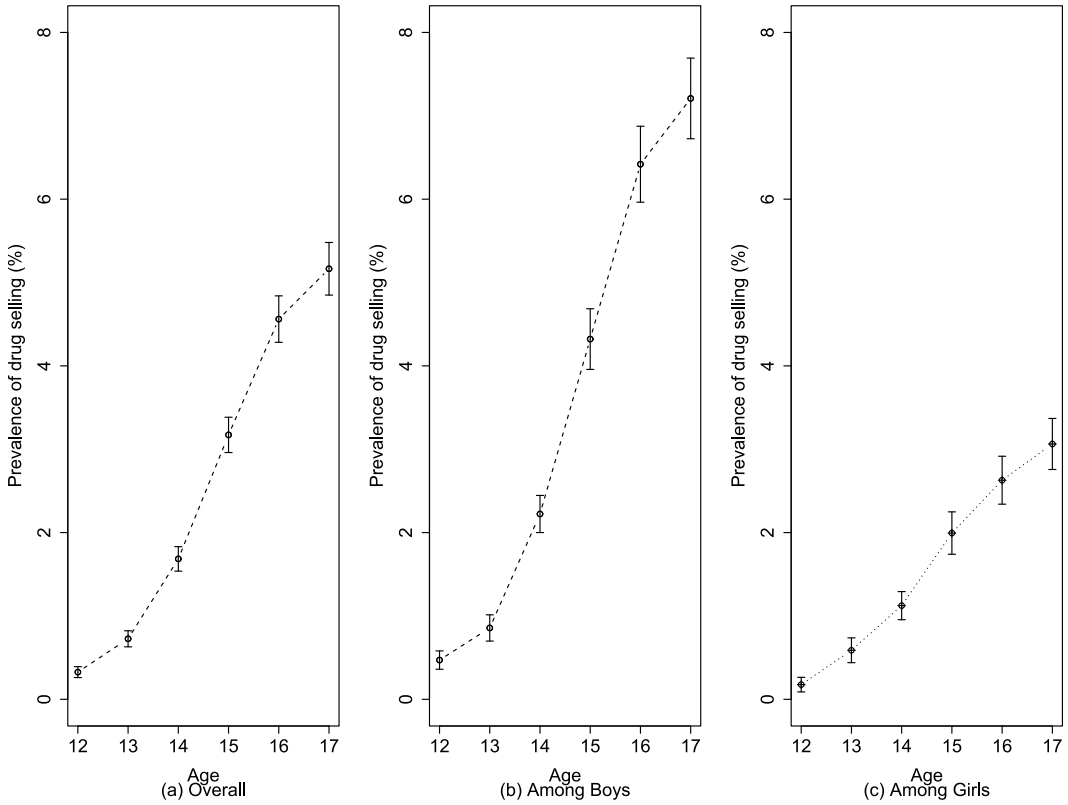

Figure 3. Age-specific prevalence of drug selling during 2005-2019.

4.2 Results for Aim 2

4.2.1 Overview

A mutoscope approach was applied to study the cohort effect and the age-specific prevalence pattern for drug selling. What is a mutoscope approach? In the early 20th century, Herman Casler invented a simple flip through the machine called "mutoscope." This machine could quickly and successively flip a series of cross-sectional snapshots to depict objects in motion. When the mutoscope approach is applied to a sequence of annually repeated cross-sectional surveys, I can have a dynamic view of cohort development. Here, the mutoscope view of cohort development can be formed by a separate set of age-specific prevalence estimates based on the numbers of recent drug sellers at specific ages divided by all youths at those ages. The table formed by prevalence estimates begins with 12-year-olds in the 2005 survey year. The column-wise estimates show a time-dependent pattern for a given age. The row-wise estimates present an age-related pattern each year. The diagonal lines show the dynamics of drug sale experience for each cohort across ages and years. For example, starting with an age 12 cohort in 2005, the 13-year-olds sampled and interviewed in 2006 provide a snapshot of the drug selling status of the same cohort at their age of 13, and the 14-year-olds sampled and interviewed in 2007 provide a snapshot of the drug selling status of the same cohort at their age of 14. The remaining snapshots were generated similarly, age by age and year by year through age 17 and year 2019.

4.2.2 Results

Table 4 shows the sample of 12-to-17-year-olds who participated in the surveys from 2005 to 2019. This first cross-table shows unweighted numbers of youths who sold drugs in the past 12 months. In general, the number of drug sellers increases with age for most of the survey years, except in the

Year 2015 and Year 2017, where fewer 17-year-olds participated than 16-year-olds. In terms of years, the overall trend of drug selling is declining, but not a linear trend. Compared to 2005, the number of teenagers involved in drug selling in 2019 has decreased by half. Similar patterns are seen in the weighted counts of Table 5.

Determined by the year they were aged 12, diagonal and sub-diagonal cells (in the lower left half) of Tables 6 and 7 show the epidemiological mutoscope views of the drug selling experience of individual birth cohorts, Table 6 shows the estimated prevalences of drug selling, and Table 7 shows the 95% confidence interval. To illustrate, take a look at the diagonal starting from the Year 2005 and age 12. It corresponds to the cohort of subjects who were 12 in 2005. The first element in the diagonal shows that 4.4 (95% CI [0.06, 8.7]) out of 1000 subjects in the cohort had sold drugs 12 months before the 2005 interview. Moving along the diagonal to the 2006 assessment of an independently drawn sample from the cohort, who had turned 13 years old, the cohort-specific prevalence of drug selling had increased to 5.57 out of 1000 (95% CI [2.17, 8.98]). Then, with a completely re-drawn sample in 2007, the prevalence of drug selling for the same cohort was estimated to increase to 21.62 per 1000 (95% CI [14.65, 28.59]) at age 14. The prevalence increased to 32.25 per 1000 (95% CI [24.84, 39.65]) in 2008 when the cohort had turned 15 years old. Thereafter, subsequent estimates jumped to 53.4 per 1000 (95% CI [44.24 ,62.55]) in 2009 and peaked at age 17 in 2010, which is 60.5 per 1000 (95% CI [47.51,73.59]). Taking a mutoscope view of the tables, I can see how a cohort's drug-selling prevalence changes over time. When the drug-selling experiences of the other cohorts are traced in the same way, a congruent general pattern can be seen. Additionally, the cohorts of 2005-2010, 2012, and 2014 all show a pattern that the prevalence of drug selling increased with age. However, I cannot see this pattern for the cohorts of 2011 and 2013.

The last two rows of Table 6 show the age-specific meta-analysis summary estimates and confidence intervals obtained by summarizing the 15 age-specific prevalence estimates and their standard errors over the 15 years. The meta-analyses show that the prevalence monotonically increases with age, reaching the peak at age 17.

Table 4. Unweighted numbers of youths who sold drugs in the past 12 months by age and year (data from National Surveys on Drug Use and Health, United States 2005–2019).

Age	**12**	**13**	**14**	**15**	**16**	**17**
Year	**Number of youth drug sellers in the sample**					
2005	13	32	64	131	183	231
2006	13	25	57	137	193	199
2007	8	27	71	127	186	187
2008	8	18	63	105	185	219
2009	10	33	61	135	183	226
2010	8	28	56	131	180	197
2011	10	37	71	117	171	206
2012	10	22	62	109	138	162
2013	6	25	41	109	145	153
2014	6	9	29	64	96	111
2015	12	13	32	68	121	96
2016	9	9	40	63	74	109
2017	8	16	39	59	111	101
2018	10	12	20	63	86	101
2019	6	18	32	65	73	95

Table 5. Weighted population counts of youth drug sellers by age and year (data from National Surveys on Drug Use and Health, United States 2005–2019).

Age	12	13	14	15	16	17
Year	**Corresponding weighted counts of youth drug sellers in the US population**					
2005	17,222	51,517	69,936	166,005	245,231	265,013
2006	14,877	22,929	79,950	174,222	261,080	280,751
2007	7,978	37,152	88,544	178,786	217,738	215,650
2008	12,584	29,347	87,406	140,878	203,434	272,549
2009	11,890	50,017	89,803	166,295	225,064	251,859
2010	6,140	42,691	70,220	175,755	228,162	255,585
2011	17,556	36,515	86,773	146,628	221,445	260,444
2012	10,062	24,070	85,561	136,968	194,810	229,342
2013	14,256	33,049	48,177	119,608	173,856	203,864
2014	9,048	12,617	49,484	101,845	136,648	185,371
2015	14,612	21,367	43,481	112,414	220,368	173,183
2016	11,073	11,002	70,522	112,205	128,128	172,665
2017	10,650	25,082	67,761	95,320	193,758	152,243
2018	14,065	16,521	41,543	92,373	146,692	173,639
2019	15,289	29,258	81,750	111,701	126,549	158,996

Table 6. Estimated prevalence of drug selling, stratified by age at assessment and survey year, and age-specific meta-analysis summary estimates. Data from National Surveys on Drug Use and Health, United States 2005–2019.

Age	12	13	14	15	16	17
Year	Estimated prevalence of drug selling (per 1000)					
2005	4.4	12	16.2	38.3	56.6	64.8
2006	3.9	5.6	18.5	38.6	60.8	66.6
2007	2	9.1	21.6	40.6	49.5	52.3
2008	3.3	7.4	21.4	32.3	47.4	63
2009	3.2	13	21.9	37.9	53.4	58.2
2010	1.6	10.6	18.2	42.5	55	60.6
2011	4.7	8.8	20.7	34.6	51.1	61.7
2012	2.5	6	20.6	33.5	45.5	53.7
2013	3.8	7.9	11	28.8	41.2	49.5
2014	2.4	3.1	12	23.6	32	44.5
2015	3.9	5.4	10	26.3	52.6	41.3
2016	3	2.7	16.9	25.6	29.7	42.2
2017	2.9	6.2	15.8	22.7	44.6	36.2
2018	3.8	4.1	9.8	22.6	33.8	40.6
2019	3.9	7	19.2	26.9	30.7	38.9
Meta-analysis	2.9	6.7	16.6	31.3	45.4	51.1
Confidence interval	**2.2,3.5**	**5.2, 8.2**	**14.3,18.8**	**27.9,34.6**	**40.5.,50.3**	**45.9,65.4**
Heterogeneity P-value	0.9396	0.0022	0.0264	0.0006	<0.0001	<0.0001

Table 7. 95% confidence intervals for age- and year-specific prevalence estimates and 95% confidence intervals for age-specific meta-analysis summary estimates. Data from National Surveys on Drug Use and Health, United States 2005–2019.

Age	12	13	14	15	16	17
year	95% Confidence interval for age- and year-specific prevalence (per 1000)					
2005	0.06,8.73	6.48,17.43	10.91,21.49	29.7,46.9	44.28,68.95	53.42,76.18
2006	1.19,6.53	2.17,8.98	12,24.94	28.8,48.34	48.82,72.71	55.4,77.82
2007	0.3,3.64	4.83,13.29	14.65,28.59	31.3,49.92	38.63,60.37	43.32,61.18
2008	0.75,5.86	2.22,12.66	14.01,28.78	24.84,39.65	39.05,55.79	49.75,76.2
2009	0.42,6.07	6.45,19.59	14.94,28.87	29.64,46.25	44.24,62.55	48.09,68.38
2010	0,3.47	5.19,15.96	11.9,24.57	33,52.08	43.21,66.78	47.51,73.59
2011	1.14,8.21	6.03,11.6	13.75,27.66	26.32,42.86	39.9,62.31	49.15,74.16
2012	0.17,4.81	2.43,9.5	13.67,27.58	25.57,41.49	35.72,55.24	41.36,66.02
2013	0,7.76	3.29,12.59	5.53,16.43	21.15,36.52	32.26,50.14	38.46,60.49
2014	0.03,4.67	0,6.32	5.75,18.19	15.44,31.85	22.44,41.63	34.67,54.27
2015	1.03,6.7	1.21,9.62	4.51,15.42	18.3,34.29	40.18,65.02	31.08,51.52
2016	0.3,5.65	0.54,4.89	9.66,24.23	18.31,32.87	19.33,40.16	32.41,52.04
2017	0.21,5.52	1.97,10.51	8.89,22.61	15.63,29.72	33.28,55.9	26.77,45.65
2018	0.56,7.1	0.98,7.12	2.82,16.73	13.93,31.27	22.31,45.31	30.08,51.07
2019	0,8.61	2.48,11.48	9.03,29.35	20.41,33.3	19.36,42.12	29.08,48.67
Meta-analysis	**2.2,3.5**	**5.2, 8.2**	**14.3,18.8**	**27.9,34.6**	**40.5,50.3**	**45.9,65.4**

4.3 Results for Aim 3

4.3.1 Overview

This chapter aims to assess the effects of ever use of drugs, drug type at first drug use, categorized elapsed time since first drug use, and type-by-elapsed-time interaction on the odds of recent drug selling. I expected that the earlier onset of IRD use is associated with an increased probability of recent drug selling. I accomplished the objective through statistical analyses of relevant data from each of the 15 NSDUHs from 2005 to 2009 and meta-analyses of the 15 sets of effect estimates obtained from the individual survey analyses. The target population is all the non-institutional adolescents (of age 12-17) in the U.S. I will first introduce the variables included in the models as

well as how to create two important variables, elapsed time and drug type at first use. I then present the resulting estimates in tables, and I finally summarize the findings.

4.3.2 Variables

The outcome variable is whether the adolescent sold drugs in the 12 months prior to the interview. The exposure variables ever use of drugs, drug type at first use (cannabis only vs. otherwise), and elapsed time from first drug use to interview, and I consider age at interview, sex, and race/ethnicity (non-Hispanic white, black, Hispanic, and other) as potential confounders.

a) Drug Type at First Use

Drug type at first use is a binary variable. For each participant aged between 12 and 17, I scanned ages at first use of LSD, PCP, cocaine, cannabis, heroin, and crack, and then I selected the minimum age (‘min age’). If the participant only used cannabis at the min age, he/she would be assigned to the cannabis-only group concerning the drug type at first use; otherwise, she/he would be assigned to the other group. The ‘otherwise’ category of the drug type is defined to be the case that at least one drug other than cannabis was used at first use regardless of whether cannabis was also used. My original plan was to compare subgroups defined by drug type at first use – that is, cannabis only, non-cannabis only, and cannabis plus at least one other internationally regulated drug. This goal was thwarted by the small number of drug-selling youths observed each year in the non-cannabis-only group; a result was a failure of model convergence. For this reason, I combined people using other IRD but no cannabis at the first time and those using both at the first time into one group.

b) Elapsed Time from Drug Onset to Assessment

In terms of elapsed time, the ideal situation is knowing the specific date of first IRD use and the specific date of interview. However, to protect the privacy of the interviewers and thwart the

identification of individuals, there is no information on the date or month of the interview. Thus, I calculated elapsed time since IRD onset by taking the difference between ages at the interview. The survey provided information on age at first drug use.

IRD use questions were as follows: “Have you ever, even once, used cannabis or hashish?” “How old were you the first time you used cannabis or hashish?” “Have you ever, even once, used any form of cocaine?” “How old were you the first time you used cocaine, in any form?” “Have you ever, even once, used LSD, also called ‘acid’?” “How old were you the first time you used LSD? “ There are similar questions for heroin, cocaine, and crack.

4.3.3 Exploratory Analysis

As I can see from Table 8, the prevalence peak of ‘never use any type of drug’ and the prevalence bottom of ‘use cannabis only’ appeared simultaneously. In 2011, the fewest people reported ‘never use any type of drug,’ but the most people reported having used cannabis only for the first time. The year 2016 was the opposite: the most people reported ‘never use any type of drug,’ but the fewest people reported having used cannabis only for the first time. Overall, the prevalence of never taking drugs is increasing, and that of using cannabis only for the first time is decreasing. For the group that used non-cannabis IRD with or without cannabis use for the first time, the peak is 1.05%, appearing in 2006. Since 2007, the prevalence of that group had decreased till I saw a big dip in 2014 to only 0.09%. After 2014, the prevalence increased a lot. This pattern coincided with the trajectory of drug selling prevalence I saw in Aim 1.

Table 8. Prevalence of each type of first IRD use among the youth aged 12-17 over 2005-2019 (data from National Surveys on Drug Use and Health, United States 2005–2019).

Year	Never use any type of drug (%)	Use of cannabis but no other IRD use (%)	Use of a non-cannabis IRD with or without concurrent cannabis use (%)
2005	15143 (82.37)	3343 (16.64)	192 (1)
2006	14942 (82.46)	3106 (16.49)	186 (1.05)
2007	14446 (83.3)	3005 (15.71)	171 (0.99)
2008	14490 (83.16)	2925 (15.93)	191 (0.91)
2009	14294 (82.7)	3061 (16.34)	172 (0.97)
2010	15048 (82.57)	3193 (16.65)	153 (0.78)
2011	15837 (82.28)	3296 (17.06)	131 (0.66)
2012	14266 (82.94)	2997 (16.31)	136 (0.75)
2013	14582 (83.78)	3052 (15.81)	102 (0.41)
2014	11224 (83.39)	2296 (15.96)	80 (0.09)
2015	11288 (83.87)	2201 (15.37)	96 (0.76)
2016	12079 (85.11)	2094 (14.2)	99 (0.69)
2017	11410 (84.3)	2203 (14.85)	109 (0.85)
2018	11113 (84.5)	2089 (14.82)	85 (0.67)
2019	11052 (83.68)	2235 (15.52)	110 (0.8)

From Table 9, I can see that the distribution of race/ethnicity is about the same between the group of never use and the group who used only cannabis at the first time, but the percentages of Hispanics and blacks have a notable change in the group who used a non-cannabis IRD with or without concurrent cannabis use at the first time. The percentage of Hispanics increased and that of blacks decreased, both by about 4%.

Table 9. The distribution of race/ethnicity by the type of first drug use among youths aged 12-17 (Data from National Surveys on Drug Use and Health, United States 2005–2019).

Race/Ethnicity	Type of first drug use		
	Never use any type of drug (%)	Use of cannabis but no other IRD use (%)	Use of a non-cannabis IRD with or without concurrent cannabis use (%)
Hispanic	38444 (19.11)	8360 (20.34)	489 (24.29)
black	27199 (13.52)	5752 (14)	204 (10.13)
other	20270 (10.07)	4306 (10.48)	226 (11.23)
white	115301 (57.3)	22678 (55.18)	1094 (54.35)
Total	201214	41096	2013

From Table 10, I see that the gender ratio is about 1:1 in the group of never use and the group who used a non-cannabis IRD with or without concurrent cannabis use the first time. However, there is one notable difference in gender in the cannabis-only group. More boys used cannabis but no other IRD at the first time than girls.

Table 10. The distribution of gender by the type of first drug use among youths aged 12-17 (Data from National Surveys on Drug Use and Health, United States 2005–2019).

GENDER	Type of first drug use or never use a drug		
	Never use any type of drug (%)	Use of cannabis but no other IRD use (%)	Use of a non-cannabis IRD with or without concurrent cannabis use (%)
Male	102066 (50.73)	21590 (52.54)	989 (49.13)
Female	99148 (49.27)	19506 (47.46)	1024 (50.87)
Total	201214	41096	2013

4.3.4 Results from The Logistic Models and Meta-Analysis

Based on the logistic regressions, I estimated the odds ratios associated with comparing users of each drug type vs. never users at every value of elapsed time and the ORs associated with elapsed time for each drug type. These results are given in appendix part A. The corresponding OR estimates based on the meta-analysis are given in Tables 11 and 14. The model estimation with the 2015 survey data did not converge. So, I do not report the ORs for 2015. According to Tables 11 and 14, there is robust and precise evidence that the odds of recent drug selling for cannabis only users increases with the elapsed time and also robust evidence that adolescent cannabis only users have a robust higher odds of recent drug selling than adolescents who have never used any drug. The effect of only cannabis use on drug selling does not change across the years. Table 11 to Table 14 shows that adolescent drug users who start with non-cannabis IRD and possible cannabis have noteworthy higher odds of recent drug selling than adolescents who have never used any drug, and those users

also have a higher odds of recent drug selling than the users who start with cannabis only. Table 11, Table 12, Table 13 and Table 14 also show that the odds of recent drug selling for users who start with non-cannabis IRD and possible cannabis does not change with elapsed time except that those users have a noteworthy higher odds of selling drugs at the 3rd year since the first drug use than the other years.

Table 11. Meta odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent only marijuana users and adolescent non-users based on the 2005- 2019 survey. The p-values of the tests for OR heterogeneity across the years are also reported*.

	Type of drug first used		
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use		
	OR (CI)	P-value	P-value of the heterogeneity test
0	16.91 (14.27, 20.04)	<.0001	0.64
1	26.93 (22.93, 31.63)	<.0001	0.13
2	45.51 (39.26, 52.75)	<.0001	0.24
3	71.18 (61.73, 82.08)	<.0001	0.43
4+	96.16 (83.56, 110.66)	<.0001	0.55
Never use	Ref.	NA	NA

*2015 was excluded from the above meta-analysis because the model estimation could not converge.

Table 12. Meta odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent non-cannabis IRD with or without concurrent cannabis users and adolescent non-users based on the 2005- 2019 survey. The p-value of the tests for OR heterogeneity across the years are also reported*.

	Type of drug first used		
Elapsed time since first use (yrs)	Use of a non-cannabis IRD with or without concurrent cannabis use		
	OR (CI)	P-value	P-value of the heterogeneity test
0	21.64 (0.96, 489.62)	0.0540	<.0001
1	88.88 (60.33, 130.94)	<.0001	0.09
2	95.47 (62.36, 146.18)	<.0001	0.18
3	132.14 (87.06, 200.58)	<.0001	0.56
4+	99.41 (64.53, 153.14)	<.0001	0.27
Never use	Ref.	NA	NA

*2015 was excluded from the above meta-analysis because the model estimation could not converge.

Table 13. Meta odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent only marijuana users and adolescent non-users based on the 2005- 2019 survey. The p-values of the tests for OR heterogeneity across the years are also reported*.

	Type of drug first used		
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use		
	OR (CI)	P-value	P-value of the heterogeneity test
0	0.17 (0.15, 0.20)	<.0001	0.74
1	0.27 (0.24, 0.31)	<.0001	0.40
2	0.47 (0.42, 0.52)	<.0001	0.52
3	0.72 (0.63, 0.81)	<.0001	0.95
4+	Ref.	NA	NA

*2015 was excluded from the above meta-analysis because the model estimation could not converge.

Table 14. Meta odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent non-cannabis IRD with or without concurrent cannabis users and adolescent non-users based on the 2005- 2019 survey. The p-values of the tests for OR heterogeneity across the years are also reported*.

	Type of drug first used		
Elapsed time since first use (yrs)	Use of a non-cannabis IRD with or without concurrent cannabis use		
	OR (CI)	P-value	P-value of the heterogeneity test
0	0.25 (0.06, 1.02)	0.05	<.0001
1	0.90 (0.47, 1.71)	0.75	0.05
2	0.94 (0.53, 1.69)	0.85	0.24
3	71.18 (61.73, 82.08)	<.0001	0.43
4+	Ref.	NA	NA

*2015 was excluded from the above meta-analysis because the model estimation could not converge.

4.4 Results for Aim 4

4.4.1 Overview

Despite a small set of prior studies that help to substantiate the existence of an association between drug use and drug selling, very few empirical studies have addressed the temporal sequencing issue.

The result is uncertainty about temporality when a goal is to estimate causal relationships between drug use and selling. This situation is understandable since following adolescents from being drug-free to becoming drug dealers is costly and time-consuming. It is even harder to follow drug dealers from being drug-free to becoming drug users. In this study, I have not solved this problem, but I have set up a time lag from drug use to drug selling, and then I contrasted the group of never using any type of drug to the group whose first drug is only cannabis. The result is a novel view of the odds of selling drugs during a 12–15-month interval observed after first drug use.

My original proposal for this dissertation research project did not include this study feature. After seeing the results of Aim 3, I noticed that for elapsed time=0, 1 yr group, whose first drug use and drug selling happened in the same age or drug use age one year before survey age. There is no precise time order for these two groups like elapse time =2, 3, 4 yr. For example, one youth started to use the first drug at age 11, and his birthday was the end of November. When assessed the following year at age 12, his elapsed time=1. However, because participants were asked, "How many times have you sold illegal drugs in the past 12 months?" it is possible he sold drugs in October when he was 11. When elapsed time =0, there is no way to identify the time sequence between drug use and drug selling based on current datasets, but I can figure out the time sequence for elapsed time =1 group. I decided to add this analysis, just focusing on the group of cannabis use with onset during the 15-month interval prior to drug selling. I will describe how to create the target population and variables then summarize the findings in this chapter.

4.4.2 Target Population

I accomplished the objective through statistical analyses of relevant data from 15 NSDUHs from 2005 to 2009 and meta-analyses of the 15 sets of effect estimates obtained from the individual survey analyses. The target population is the non-institutional adolescents who either have never used any

drug (opioid use was also excluded) or whose first drug use occurred 12-24 months before the survey quarter. Since the survey data sets do not contain the exact interview date of each respondent but have the quarter in which the interview was conducted. The time window of 12-24 months before the survey interview is set to be 12-24 months before the first day of the interview quarter. To make sure cannabis users whose age of onset occurred before drug sell. II applied 15 months approach. Based on information of year, the month of first cannabis use, year/quarter of assessment, I can create a 15-month window. If the first cannabis use happened 15 months prior to each assessment quarter's first month/ last month, they are eligible for this study. Take people surveyed in the year of 2005 quarter one as an example. His first time of cannabis use must fall in 200301-200312.

4.4.3 Variables

The outcome variable is whether the adolescent sold drugs in the 12 months before the interview. The exposure variable is the binary variable indicating whether the subject has never used any drug or his/her first drug was cannabis, and I consider age at interview, sex, and race (white, black, Hispanic, and other) as potential confounders. In this study, the elapsed time since cannabis onset is measured using the month-by-month information after the month of cannabis first use, measured by the ACASI cannabis use module, relative to the quarter of NSDUH assessment. Cannabis use questions were as follows: “Have you ever, even once, used cannabis or hashish?” “How old were you the first time you used cannabis or hashish?” “Did you first use cannabis or hashish in [CURRENT YEAR-1], or [CURRENT YEAR]?” “In what month in [YEAR] did you first use cannabis or hashish?”

4.4.4 Results

I apply logistic regression to the data of each of the 15 surveys and then perform a meta-analysis of the 15 sets of effect estimates using DerSimonian and Laird's random effects approach (DerSimonian & Laird, 1986). There are two types of logistic regression models in the analysis. One has only one covariate, the binary variable indicating whether the subject has never used any drug or his/her first drug was cannabis. The other has additional covariates of age at interview, sex, and race, i.e., adjusting for the potential confounders. The outcome variable for both types of logistic regression models is whether the adolescent sold drugs 12 months prior to the interview. Based on the logistic regressions, I estimated the odds ratios (ORs) associated with comparing never users and users whose first drug is cannabis, adjusting or not adjusting for the potential confounders. The marginal and the adjusted odds ratio estimates are given in Table 41 and Table 42, respectively. Those two tables also give the corresponding ORs based on the meta-analyses and the OR heterogeneity test results. This table shows that the average unadjusted OR of drug selling between never users and users whose first drug is cannabis is 23.67 and that there is robust and precise heterogeneity in the OR among different years. Table 42 shows that the average adjusted OR of drug selling between never users and users whose first drug is cannabis is 19.26 and that there is also robust and precise heterogeneity in the OR among different years.

Table 15. Unadjusted odds ratios between never users and users whose first drug is cannabis and the 95% confidence intervals by year.

Year	Odds Ratio*	95% CI
2005	25.58	(11.93, 54.87)
2006	74.31	(34.5, 160.06)
2007	30.04	(15.35, 58.77)
2008	23.79	(9.94, 56.92)
2009	18.78	(9.59, 36.78)
2010	37.28	(14.82, 93.79)

Table 15 (cont'd)

2011	18.70	(9.83, 35.56)
2012	28.35	(11.57, 69.46)
2013	23.36	(9.32, 58.56)
2014	14.62	(4.29, 49.90)
2015	4.38	(1.50, 12.81)
2016	40.14	(20.5, 78.59)
2017	16.86	(7.19, 39.53)
2018	16.79	(7.01, 40.19)
2019	22.21	(9.71, 50.81)
Meta-analysis	23.67	(17.86, 31.36)
P-value for the heterogeneity test		0.0267

* The odds of drug selling are based on a standardized survey question about the 12 months interval prior to the assessment date. As studied here, the onset of cannabis use always preceded that at least12 month interval for assessment of drug use. The text explains how the month and year of first use made it possible to identify the onset of use that pre-dated the months of being a drug seller so that the odds of starting to use could be evaluated for the 'prevalent cases' of drug selling versus those who did not qualify as 'prevalent cases' of drug selling.

Table 16. Confounder-adjusted odds ratios between never users and users whose first drug is cannabis and the 95% confidence intervals by year.

Year	Odds Ratio*	95% CI
2005	18.97	(8.37, 42.98)
2006	57.56	(24.51, 135.16)
2007	28.54	(12.80, 63.64)
2008	18.23	(6.92, 48.04)
2009	13.39	(6.27, 28.60)
2010	29.63	(9.32, 94.16)
2011	14.02	(6.35, 30.94)
2012	21.45	(8.03, 57.31)
2013	19.90	(6.89, 57.48)
2014	10.46	(2.79, 39.27)
2015	3.50	(1.11, 11.03)
2016	41.58	(20.63, 83.79)
2017	17.17	(6.28, 46.98)
2018	11.6	(4.74, 28.41)
2019	21.42	(8.84, 51.91)
Meta-analysis	19.26	(14.08, 26.36)
the p-value for the heterogeneity test		0.0286

* The odds of drug selling are based on a standardized survey question about the 12 months interval prior to the assessment date. As studied here, the onset of cannabis use always preceded that at least12 month interval for assessment of drug use. This model adjusted for age, gender, race/ethnicity.

CHAPTER 5

MAIN FINDINGS AND LIMITATIONS

5.1 Overview

The main findings of the current research are summarized in this chapter. The first section of this chapter will recap principal findings for each specific aim. The second section includes a discussion of study limitations. Finally, I will talk about the strength of the current study.

5.2 Summary of Study Findings

This study aimed to address gaps in our understanding of overall trends and correlates of drug selling among youth aged 12-17. I focused on how the age of first drug use, elapsed time, and prior cannabis use would affect youth drug selling behavior.

The study's first aim was to access the age-specific drug selling prevalence, recent drug selling behaviors, and trends. I see the prevalence of drug selling plummeted from 3.22 in 2005 to 1.99 in 2014, and the prevalence went up and down from 2015-2019, but overall trends were declining. I also observed sex and age difference. Drug selling prevalence increase with age for both boys and girls. However, I see parallel growth for boys and girls at age 12-13. From age 13-14, the slopes for

boys and girls were different. The growth rate of boys is fast, while the growth rate for girls is relatively flat.

The second aim was to access the mutoscope view of recent drug selling among youth. When the drug selling experience of each cohort is traced monoscopically down each diagonal, a general pattern can be seen. The mutoscope pattern is the same as the age-specific pattern for cohorts 2005-2010, 2012, and 2014. For those seven cohorts, the drug-selling estimates went up from age 12- age 17, the estimates of 17 years old are higher than any previous age. However, for cohorts 2011, 2013, and 2015, there is no monotonically increase in age-specific drug selling prevalence. For cohort 2011 and 2013, they reach the peak at age 16 and then drop at age 17. I also see the estimates dropped from age12 to age 13 for cohorts 2013 and 2015.

The third aim was to access the association between recent drug selling and elapsed time (since onset age of IRD used to survey age) and type of IRD first used (cannabis vs. IRD with or without cannabis use). The statistical analyses of the NSDUH data from 2005-2019 show that starting using only cannabis increases the odds of drug selling in the subsequent years for adolescents. The longer it elapses from the first use, the higher the odds of drug selling. If a non-cannabis IRD is used at the first drug use, the odds of drug selling will be even higher in the subsequent years than adolescents who use only cannabis the first time. However, unlike cannabis only users, the odds of recent drug selling for users who start with non-cannabis IRD and possible cannabis does not change obviously with elapse time except that those users have a remarkable higher odds of selling drugs in the 3rd year since the first drug use than the other years.

The fourth aim was to compare never users and users whose first drug is marijuana concerning their odds of selling drugs 12 months after first drug use. The statistical analyses found that adolescents who start to use cannabis but no other drug are much more likely to sell drugs during the 12 months

after the first use, compared to adolescents who have never used any drug. This conclusion is proper, even accounting for age, race, and sex. There is a heterogeneity in the effect of cannabis on drug selling across different years, but no trend over the years was observed from the analysis results.

5.3 Study Limitation and Strengths

a) Anticipated Limitations:

Many of the limitations come from the NSDUH survey methodology. The credibility of epidemiological survey research of this type can be constrained by non-participation of some participants (e.g. those engaged in illegal behaviors such as drug selling), sensitive questions about behaviors that youths might wish to remain undisclosed, and other self-report validity issues, external validity such as generalizations beyond the experiences of the US adolescent populations during 2005 through 2019, and measurement equivalence issues. For example, limitations with respect to assessing the critical response variable "sold illegal drugs in the past year" was derived from youth self-reports. Some youths might not wish to disclose this misbehavior. Alternately, some youths might display correlated responses (e.g., if they are willing to disclose drug use and also to disclose drug selling). which would lead to "reporting measurement errors" (Beaver & Barnes, 2012). Similar issues surface in the measurement of the main exposure variables of IRD use. If non-response rates are high among drug sellers or drug users but low among non-seller or non-drug users, the reliability and validity of results can be affected adversely.

Moreover, this dissertation research project's results may challenge reliability to the extent that the analysis uses answers to long-term recalled questions of the age of first cannabis or other IRD use. In addition, the sampled individuals sometimes come from the same regions and block groups, and

sometimes there are multiple people in the same dwelling unit. In consequence, sharing the neighborhood and residential characteristics can make the observations more similar, violating the independent observations assumptions for variance estimation with simpler random samples. In theory, the Taylor series approaches to variance estimation should address these issues.

I also note that institutionalized youths and youths under age 12 were not sampled for this study (i.e., were outside the population specifications and sampling frames). To some extent, this exclusion constrains the generalizability of the findings.

Moreover, considering the cross-sectional study design, an important disadvantage is an inability to discern a temporal sequencing between the IRD onset and the drug selling; therefore, it is unclear whether IRD onset leads to drug selling or the opposite.

Finally, lack of timely information about drugs being sold creates uncertainty between drug use and drug selling. Future studies can improve upon this work by asking youths what drugs they used, when they first used them, what drugs they sold, and when they first sold them.

b) Strengths:

Despite limitations such as these, the most severe limitation might be the absence of a prospective cohort or longitudinal research approach. It must be noted that it is complicated and expensive to conduct prospective cohort or longitudinal repeated measures research with nationally representative samples of 12-to-17-year-old. Here, the fourth study to some extent addresses the uncertainties about the temporal sequencing of these two distinctive drug-related behaviors by setting up time order, which enables us to see how drug selling is influenced by IRD onset. The current research use existed nationwide surveys from 2005-2019 could save a lot of money and time. Besides that, the large sample size could improve the precision and external validity. I did meta-analysis rather than

a pooled analysis which allows the variation across different surveys. Although the three is not the second party to verify the outcome of drug selling, the ACASI helps for more reliable reporting of drug-related behaviors. The extent of the limitation of excluded institutionalized youth can be quantified using US Census data from 2000, 2010, and 2020 (e.g., census findings on how many 12-17-year-old are in institutions).

CHAPTER 6

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

6.1 Conclusion

The main findings of each aim of this dissertation research project are summarized below.

(1) Main findings under Aim 1: The estimated prevalence of recent drug selling (selling in the past 12 months) among 12-17 years old dropped from 2009 to 2014, with oscillations during the years before and after that time window. The estimated age-specific prevalence increased with age during 2005-2019. Male adolescents are more likely to sell drugs than female adolescents.

(2) Main findings under Aim 2: In general, the age-specific prevalence of recent drug selling in each of the birth cohorts of 1993-2002 increased with age over the age period of 12-17. However, the prevalence dropped from ages 16 to 17 in the cohorts of 1999 and 2001, and the prevalence dropped from ages 12 to 13 in the 2001 cohort. These exceptions to the general patterns remain unexplained and might be traced to issues of statistical precision in the age-specific estimates year by year.

(3) Main findings under Aim 3: The estimated odds of recent drug selling for cannabis-only users increase with elapsed time since first use during the intervals under study in this project. Adolescent cannabis-only users have greater odds of recent drug selling than adolescents who have never used any drug. Adolescent drug users who started with non-cannabis IRD and possible cannabis have greater odds of recent drug selling than adolescents who have never used any drug and the users who started with cannabis only. The odds of recent drug selling for users who started with non-cannabis

IRD and possible cannabis do not change appreciably with elapsed time since first use during the interval under study here.

(4) Main findings under Aim 4: In general, the estimated odds of drug selling for users whose first drug is cannabis is larger than the estimates for never users, adjusting age at interview, sex, and race/ethnicity. However, the odds ratio measure of association can be seen to vary with the calendar year.

6.2 Implications

The findings reported in this study may have several important implications. First, there is evidence of that starting to use cannabis has been associated with an increased odds of drug selling. The longer elapsed time since first-time use, the higher chance to be a drug seller – i.e., a vector who conveys a drug from its reservoir to susceptible hosts. The implications include a highlight when I consider the importance of preventing the onset of cannabis among adolescents. Especially in the current environment of legalization and liberalization of cannabis policies, there is some initial evidence that the prevalence of cannabis use has increased ((Hasin et al., 2015; Johnson et al., 2015). On one hand, it is crucial to conduct interventions that target the reduction of exposure to cannabis among adolescents. On the other hand, more attention to users who started with a non-cannabis IRD than users who started with cannabis only regarding drug selling. It is crucial to conduct interventions that target the reduction of exposure to non-cannabis IRD among adolescents. Because the third study found that a non-cannabis IRD was used at the first drug use. The odds of drug selling might be even higher in the subsequent years than adolescents who used only Cannabis for the first time. These results highlight the advantages of reducing the risk of starting to use other non-cannabis IRD.

Second, I noticed that there is a huge jump in the prevalence of drug selling from age 12 to age 13 in both cohorts 1993-1998, and another jump in the prevalence of drug selling from age 23 to age 14 in birth cohort 1999-2001. This evidence indicated that preventive interventions of drug selling should be started no later than 14 years of age, and we should apply preventive interventions of drug selling to adolescent drug users as early as possible.

6.3 Future Research

Findings from my dissertation research project can serve as preliminary results that may help guide future longitudinal studies if only to facilitate their power/sample size calculations required to plan and motivate externally sponsored research funding for these projects. Researchers interested in this topic can take these findings to see whether they can also be seen in longitudinal follow-up studies that strengthen the foundation of evidence for causal inferences.

The NSDUH sampling frame excludes children younger than age 12. As a result, the estimates presented here do not reflect the occurrence of drug use and selling experiences for that younger population. However, this younger age group might be a vital population to focus on when trying to reduce the onset of IRD will provide essential findings to complement what was observed here.

The current study estimates the degree to which the odds of being a recent drug seller might be amplified in contrast of ‘cannabis only’ users versus ‘with or without cannabis + at least one other IRD’ users, with the observations based on what can be observed during a relatively short interval of observation that is time-sequenced to pre-date the interval of the observation of drug selling. I look at the months before the drug selling is based strictly on ‘cannabis onsets’ preceding ‘drug

selling' odds. A future direction for research can include a contrast of the 'cannabis only' users versus the 'cannabis-plus-IRD' users.

With the novel and well-replicated estimates from US national surveys, immediate next steps can also shift to the Add Health longitudinal datasets. The longitudinal work should help us to understand and to answer some fundamental questions about becoming a "drug vector" and the conveyance of drug products from a dynamically changing "reservoir" of drug supply for "downstream" effects on human population drug use experience. By using Add Health longitudinal datasets, we can Look more deeply into the association of drug use with drug selling in subgroups studied here (e.g. male-female variations), as well as subgroups not yet studied (e.g. family income, prenatal education); study the causal pathways from drug use to the odds of becoming and being a drug seller through mediation analyses as well as study the impact of legalizing cannabis use on drug selling in adolescents.

Dynamically changing environmental conditions such as liberalized cannabis sales policies of the past 10 years might have helped shift the odds of being a drug seller in a recent downward direction, and the covid pandemic social distancing might have added to sustain this downward trend. These potential influences remain unexplored territories for future research.

APPENDICES

APPENDIX A: Odds Ratio Estimates of Drug-Selling Over Elapsed Time of Only Cannabis Use and Non-Cannabis IRD with or without Cannabis use.

Table 17. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2005 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	19.56 (11.45, 33.43)	20.58 (4.13, 102.48)
1	17.8 (11.55, 27.43)	64.81 (22.99, 182.66)
2	33.12 (22.39, 49)	73.53 (22, 245.8)
3	59.67 (38.09, 93.47)	224.74 (63.63, 793.77)
4+	74.68 (51.11, 109.12)	46.49 (13.98, 154.53)
Never use	Ref.	Ref.

Table 18. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2005 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.26 (0.15, 0.45)	0.44 (0.08, 2.5)
1	0.24 (0.17, 0.34)	1.39 (0.23, 8.43)
2	0.44 (0.32, 0.61)	1.58 (0.31, 8.14)
3	0.8 (0.56, 1.13)	4.83 (1.39, 16.78)
4+	Ref.	Ref.

Table 19. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2006 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	13.85 (7.91, 24.23)	73.58 (19.63, 275.83)
1	34.23 (21.84, 53.67)	109.01 (39.82, 298.43)
2	47.91 (29.66, 77.4)	45.88 (12.63, 166.69)
3	63.67 (40.09, 101.13)	114.57 (27.75, 472.99)
4+	81.66 (49.59, 134.48)	159.25 (58.48, 433.67)
Never use	Ref.	Ref.

Table 20. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2006 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.17 (0.09, 0.3)	0.46 (0.09, 2.38)
1	0.42 (0.28, 0.63)	0.68 (0.16, 2.97)
2	0.59 (0.37, 0.93)	0.29 (0.06, 1.29)
3	0.78 (0.51, 1.2)	0.72 (0.14, 3.76)
4+	Ref.	Ref.

Table 21. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2007 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	15.71 (9.59, 25.73)	101.7 (27.68, 373.65)
1	25.19 (16.43, 38.62)	212.21 (88.99, 506.07)
2	41.82 (27.34, 63.98)	46.27 (13.98, 153.15)
3	61.03 (37.48, 99.39)	111.11 (23.88, 516.95)
4+	82.36 (53.59, 126.57)	36.45 (8.08, 164.32)
Never use	Ref.	Ref.

Table 22. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2007 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.19 (0.11, 0.32)	2.79 (0.4, 19.26)
1	0.31 (0.21, 0.45)	5.82 (1.34, 25.22)
2	0.51 (0.34, 0.75)	1.27 (0.21, 7.62)
3	0.74 (0.49, 1.11)	3.05 (0.34, 27.33)
4+	Ref.	Ref.

Table 23. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2008 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	22.63 (10.95, 46.78)	239.07 (68.41, 835.47)
1	31.47 (19.09, 51.87)	122.52 (53.43, 280.96)
2	54.23 (31.7, 92.76)	47.72 (16.75, 135.96)
3	94.56 (56.12, 159.32)	189.91 (65.21, 553.13)
4+	131.99 (74.54, 233.72)	47.82 (10.4, 220)
Never use	Ref.	Ref.

Table 24. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2008 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.17 (0.08, 0.35)	5 (0.82, 30.49)
1	0.24 (0.17, 0.34)	2.56 (0.51, 12.87)
2	0.41 (0.27, 0.62)	1 (0.17, 5.98)
3	0.72 (0.47, 1.09)	3.97 (0.85, 18.49)
4+	Ref.	Ref.

Table 25. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2009 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	24.8 (13.86, 44.39)	9.25 (1.37, 62.29)
1	22.95 (13.89, 37.9)	68.56 (23.82, 197.31)
2	50.38 (33.3, 76.22)	289.47 (117.12, 715.42)
3	74.07 (45.2, 121.39)	98.63 (22.28, 436.53)
4+	108.58 (71.01, 166.02)	194.91 (69.02, 550.4)
Never use	Ref.	Ref.

Table 26. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2009 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.23 (0.13, 0.4)	0.05 (0.01, 0.38)
1	0.21 (0.13, 0.35)	0.35 (0.09, 1.38)
2	0.46 (0.33, 0.65)	1.49 (0.45, 4.91)
3	0.68 (0.45, 1.04)	0.51 (0.09, 3)
4+	Ref.	Ref.

Table 27. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2010 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	23.57 (12.41, 44.79)	55.86 (14.41, 216.5)
1	37.34 (20.77, 67.12)	133.4 (49.27, 361.18)
2	67.6 (40.32, 113.33)	102.46 (23.93, 438.59)
3	108.68 (62.46, 189.11)	250.32 (41.31, 1516.91)
4+	148.86 (83.11, 266.61)	336.32 (63.67, 1776.61)
Never use	Ref.	Ref.

Table 28. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2010 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.16 (0.09, 0.27)	0.17 (0.02, 1.52)
1	0.25 (0.17, 0.36)	0.4 (0.06, 2.45)
2	0.45 (0.31, 0.68)	0.3 (0.04, 2.32)
3	0.73 (0.49, 1.1)	0.74 (0.08, 6.92)
4+	Ref.	Ref.

Table 29. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2011 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	16.38 (8.84, 30.37)	16.34 (3.43, 77.81)
1	28.79 (19.04, 43.55)	113.35 (33.57, 382.8)
2	38.36 (24.83, 59.26)	71.05 (6.53, 772.55)
3	51.39 (31.75, 83.19)	66.79 (17.48, 255.26)
4+	97.25 (60.32, 156.77)	56.45 (14.16, 224.99)
Never use	Ref.	Ref.

Table 30. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2011 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.17 (0.09, 0.31)	0.29 (0.04, 2.23)
1	0.3 (0.2, 0.44)	2.01 (0.39, 10.42)
2	0.39 (0.26, 0.59)	1.26 (0.09, 18.27)
3	0.53 (0.35, 0.79)	1.18 (0.19, 7.37)
4+	Ref.	Ref.

Table 31. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2012 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	13.03 (6.57, 25.83)	54.07 (8.14, 358.98)
1	24.92 (15.61, 39.8)	193.99 (50.62, 743.39)
2	50.88 (28.22, 91.72)	81.94 (18.26, 367.71)
3	82.53 (48.61, 140.11)	266.77 (85.58, 831.63)
4+	123.66 (55.07, 277.7)	268.16 (48.47, 1483.45)
Never use	Ref.	Ref.

Table 32. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2012 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.11 (0.05, 0.24)	0.2 (0.02, 2.43)
1	0.2 (0.12, 0.34)	0.72 (0.1, 5.09)
2	0.41 (0.24, 0.7)	0.31 (0.04, 2.57)
3	0.67 (0.36, 1.23)	0.99 (0.13, 7.48)
4+	Ref.	Ref.

Table 33. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2013 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	16.63 (8.1, 34.15)	9.35 (1.01, 86.5)
1	31.21 (18.63, 52.28)	45.05 (9.36, 216.89)
2	52.69 (30.38, 91.37)	75.04 (9.47, 594.61)
3	66.36 (34.88, 126.25)	57.32 (6.86, 478.66)
4+	88.1 (51.59, 150.44)	106.67 (22.29, 510.56)
Never use	Ref.	Ref.

Table 34. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2013 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.19 (0.11, 0.34)	0.09 (0.01, 1.39)
1	0.35 (0.25, 0.51)	0.42 (0.07, 2.72)
2	0.6 (0.4, 0.88)	0.7 (0.04, 13.05)
3	0.75 (0.47, 1.2)	0.54 (0.04, 7.41)
4+	Ref.	Ref.

Table 35. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2014 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	18.39 (9.41, 35.94)	0 (0, 0)
1	31.06 (16.5, 58.46)	133.31 (19.27, 922.37)
2	37.85 (20.66, 69.35)	470.68 (73.15, 3028.62)
3	96.55 (53.11, 175.52)	233.03 (16, 3394.48)
4+	113.45 (51.98, 247.61)	14.4 (1.25, 165.5)
Never use	Ref.	Ref.

Table 36. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2014 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.16 (0.08, 0.34)	0 (0, 0)
1	0.27 (0.16, 0.47)	9.26 (0.47, 184.12)
2	0.33 (0.2, 0.56)	32.69 (2.7, 395.23)
3	0.85 (0.48, 1.52)	16.19 (0.47, 552.66)
4+	Ref.	Ref.

Table 37. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2016 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	24.62 (11.18, 54.21)	93.61 (25.55, 343.02)
1	52.9 (29.92, 93.53)	5.89 (1.15, 30.28)
2	89.49 (49.89, 160.52)	200.23 (51.19, 783.28)
3	117.8 (62.79, 221.01)	23.24 (2.03, 266.1)
4+	154.11 (82.76, 286.98)	139.44 (18.54, 1048.48)
Never use	Ref.	Ref.

Table 38. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2016 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.16 (0.07, 0.36)	0.67 (0.07, 6.92)
1	0.34 (0.2, 0.59)	0.04 (0, 0.52)
2	0.58 (0.34, 0.99)	1.44 (0.17, 12.13)
3	0.76 (0.46, 1.28)	0.17 (0.01, 4.73)
4+	Ref.	Ref.

Table 39. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2017 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	9.3 (4.59, 18.87)	211.82 (65.03, 690.01)
1	21.7 (12.6, 37.37)	78.47 (22.38, 275.15)
2	30.64 (17.8, 52.72)	107.44 (27.26, 423.46)
3	51.99 (30.15, 89.64)	277.31 (21.65, 3551.36)
4+	102.36 (55.28, 189.54)	269.43 (47.93, 1514.62)
Never use	Ref.	Ref.

Table 40. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2017 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.09 (0.05, 0.17)	0.79 (0.11, 5.86)
1	0.21 (0.13, 0.35)	0.29 (0.04, 2.41)
2	0.3 (0.19, 0.48)	0.4 (0.04, 3.67)
3	0.51 (0.3, 0.86)	1.03 (0.05, 22.64)
4+	Ref.	Ref.

Table 41. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2018 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	14.82 (6.16, 35.62)	34.74 (6.32, 190.98)
1	23.14 (12.77, 41.93)	72.27 (12.65, 412.73)
2	50.68 (27.27, 94.2)	16.51 (1.58, 172.32)
3	73.98 (39.3, 139.26)	74.99 (7.02, 800.71)
4+	78.27 (37.76, 162.25)	62.05 (12.7, 303.06)
Never use	Ref.	Ref.

Table 42. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2018 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.19 (0.08, 0.44)	0.56 (0.06, 5.02)
1	0.3 (0.16, 0.54)	1.16 (0.13, 10.84)
2	0.65 (0.4, 1.06)	0.27 (0.02, 4.06)
3	0.95 (0.5, 1.78)	1.21 (0.08, 18.05)
4+	Ref.	Ref.

Table 43. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey between adolescent drug users and adolescent non-users based on the 2019 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	9.73 (4.22, 22.42)	218.31 (29.04, 1641.08)
1	12.66 (6.19, 25.86)	53.57 (15.77, 181.99)
2	33.16 (19.08, 57.63)	126.02 (30.95, 513.16)
3	45.94 (20.56, 102.61)	9.61 (0.61, 151.44)
4+	62.7 (33.37, 117.82)	53.39 (4.35, 655.08)
Never use	Ref.	Ref.

Table 44. Odds ratio estimates with 95% confidence intervals of selling drugs in the 12 months prior to survey associated with elapsed time since first use based on the 2019 survey.

	Type of drug first used	
Elapsed time since first use (yrs)	Use of cannabis but no other IRD use	Use of a non-cannabis IRD with or without concurrent cannabis use
0	0.16 (0.08, 0.3)	4.09 (0.16, 103.54)
1	0.2 (0.11, 0.37)	1 (0.06, 16.04)
2	0.53 (0.31, 0.89)	2.36 (0.13, 41.33)
3	0.73 (0.38, 1.43)	0.18 (0.01, 2.51)
4+	Ref.	Ref.

APPENDIX B: Survey Methodology

Stratification and Selection of Primary, Secondary, and Tertiary Sampling Units (Census Tracts, Census Block Groups, and Area Segments)

Within each state, sampling strata called state sampling regions (SSRs) were formed. Based on a composite size measure, states were partitioned geographically into roughly equally sized regions. In other words, regions were formed such that each area within a state yielded, in expectation, roughly the same number of interviews during each data collection period. The partitioning divided the United States into a total of 750 SSRs, resulting from 36 SSRs in California; 30 SSRs each in Florida, New York, and Texas; 24 SSRs each in Illinois, Michigan, Ohio, and Pennsylvania; 15 SSRs each in Georgia, New Jersey, North Carolina, and Virginia; and 12 SSRs each in the remaining 38 states and the District of Columbia.

Similar to the 2005 through 2013 surveys, the first stage of selection for the 2014 through 2022 NSDUHs was census tracts. The first stage of selection began with the construction of an area sample frame that contained one record for each census tract in the United States.

If necessary, census tracts were aggregated within SSRs until each tract11 met the minimum dwelling unit12 (DU) requirement. In California, Florida, Georgia, Illinois, Michigan, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Texas, and Virginia, this minimum size requirement was 250 DUs in urban areas and 200 DUs in rural areas.13 In the remaining states and the District of Columbia, the minimum requirement was 150 DUs in urban areas and

100 DUs in rural areas. These census tracts served as the primary sampling units (PSUs) for the coordinated 9-year sample.

Before selecting census tracts, additional implicit stratification was achieved by sorting the first-stage sampling units by a CBSA/SES14 (core-based statistical area/socioeconomic status) indicator15 and by the percentage of the population who are non-Hispanic and white. From this well-ordered sample frame, 48 census tracts per SSR were selected with probabilities proportionate to a composite size measure and with minimum replacement.

For the second stage of selection, adjacent census block groups were collapsed as needed within selected census tracts. Compared with years prior to 2014, the selection of census block.

For the remainder of the discussion, first-stage sampling units are referred to as "census tracts" even though each first-stage sampling unit contains one or more census tracts. DU counts were obtained from the 2010 decennial census data supplemented with revised population counts from Claritas, which is a market research firm headquartered in Ithaca, New York (see https://www.claritas.com/). The basis for the differing minimum DU requirement in urban and rural areas is that it is more difficult to meet the requirement in rural areas; 100 DUs are sufficient to support one field test and two main study samples in the smaller states, and 200 DUs are sufficient to support three samples in the larger sample states. CBSAs include metropolitan and micropolitan statistical areas, as defined in the following reference:

Office of Management and Budget. (2009, December 1). OMB Bulletin No. 10-02: Update of statistical area definitions and guidance on their uses. Washington, DC: The White House. 15 The CBSA/SES indicator was defined using 2006-2010 American Community Survey (ACS) estimates,

2010 census data, and the December 2009 CBSA definition. Four categories are defined as follows: (1) CBSA/low SES, (2) CBSA/high SES, (3) non-CBSA/low SES, and (4) non-CBSA/high SES. group is an additional stage of selection that was added to facilitate possible transitioning to an address-based sample (ABS) design in the future. The block groups were required to have the same minimum number of DUs as the census tracts from which they were selected (150 or 250 in urban areas and 100 or 200 in rural areas, according to state). The resulting block groups were then sorted in the order in which they were formed, and one census block group16 was selected per selected census tract with probability proportionate to a composite size measure.

Because census block groups generally exceed the minimum DU requirement, one smaller geographic area was selected within each sampled census block group. For this third stage of sampling, each selected census block group was partitioned into small geographic areas composed of adjacent census blocks. These geographic clusters of blocks are referred to as segments and are the tertiary sampling units (TSUs) for the coordinated sample design. A sample DU in NSDUH refers to either a housing unit or a group quarters listing unit, such as a dormitory room or a shelter bed. To support the overlapping sample design and any special supplemental samples or field tests SAMHSA might wish to conduct, segments were formed to contain a minimum of 150 or 250 DUs in urban areas and 100 or 200 DUs in rural areas, according to state. One segment was selected within each sampled census block group with probability proportionate to size. The 48 selected segments then were randomly assigned to a survey year

and quarter of data collection.

Selection of Dwelling Units

The primary objective of the fourth stage of sample selection (listing units) was to select the minimum number of DUs needed in each segment to meet the targeted sample sizes for all age groups. For the 2014 through 2022 NSDUHs, each state sample was allocated to age groups as follows: 25 percent for youths aged 12 to 17, 25 percent for young adults aged 18 to 25, 15 percent for adults aged 26 to 34, 20 percent for adults aged 35 to 49, and 15 percent for adults aged 50 or older. In the 2005 through 2013 NSDUHs, the sample was allocated equally across the 12 to 17, 18 to 25, and 26 or older age groups. The 2014 through 2022 design places more sample in the 26 or older age groups to estimate drug use and related mental health measures more accurately among the aging population. The size measures used in selecting the area segments were coordinated with the DU and person selection process so that a nearly self-weighting sample could be achieved in each of the five age groups. Departures from the self-weighting objective occurred for several reasons, including the following: (a) advance projections on the number of DUs did not accurately reflect the current housing inventory; (b) maximum DU sample sizes were preset to control the interviewer workload and to allow unused addresses to be available for the next year's survey; and (c) the person selection probabilities were constrained so that no more than two individuals could be selected per DU. An iterative sample allocation process was followed to adjust for these additional constraints.

In addition, the DU sample allocation in each area segment was adjusted to allow for DU eligibility, for screening nonresponse, and for person nonresponse.

For the remainder of the discussion, second-stage sampling units are referred to as "census block groups" even though each second-stage sampling unit contains one or more census block groups.

In advance of the survey period, specially trained listers had visited each area segment and listed all addresses for housing units and eligible group quarters units in a prescribed order.

Systematic sampling was used to select the allocated sample of addresses from each segment. (https://www.datafiles.samhsa.gov/sites/default/files/field-uploads-protected/studies/NSDUH-2019/NSDUH-2019-datasets/NSDUH-2019-DS0001/NSDUH-2019-DS0001-info/NSDUH-2019-DS0001-info-codebook.pdf)

APPENDIX C: LITERATURE REVIEW

Table 45. Literature review

Authors	Year	Sample	Independent Variable	Outcome Variable	Main findings
Chein, I., Gerard, D. L., et al	1964	3475 boys aged 16-21 in New York city who involved with narcotics	Drug use, social, psychological and economic factors associated with drug use.	Drug addiction, drug selling	According to his research, we know that first-time heroin use is associated with drug selling
Altschuler, D. M., & Brounstein, P. J	1991	300 ninth-graded and tenth grade males	Delinquent behavior includes but is not limited to burglary, carrying weapon, dealing in stolen goods, shot, sexual assault	Drug involvement (drug used/sold)	Sellers were significantly more likely to carry/use weapons to threaten someone and committed more delinquent activities.
Li, X., Feigelman, S., Stanton, B.	1994	455 African American youth age 9-15	Cigarettes/alcohol and illicit drug use	Drug trafficking	Illicit drug use more likely occurs after drug trafficking
Li X,Feigelman S	1994	351 African American youth 9-15 years old	Youth's perceptions to drug trafficking	Drug trafficking	Economic motive is an important factor associated with drug dealing.

Table 45 (cont'd)

Saner, H., MacCoun, R.,et al	1995	98104 different people from 1985-1991, follow six birth cohorts	Birth cohort, age, year	Rate of participation in drug offending and other crime	Participation in drug trade was no lower than 25% for all 6 cohorts. The period effect was not linear, the peak of drug distribution in this area was 1985-1987.
Feigelman, S., Stanton, B., et al	1998	383 African-American adolescents 9–15 years of age at baseline	Cigarettes, drinking alcohol, smoking marijuana, using other illicit drugs,	selling drugs and delivering drugs.	Initiation of drug trafficking appears to lead to continued drug trafficking and drug use.
Caulkins, J. P., & Chandler, S	2006	Drug offenders in federal prisons form 1972-2002,State prison estimates from 1972-1979	Drug offenders	Proportions of drug offenders by type of charge	Adult drug trafficking proportions increased over time in late 1980s.
Little, M., Steinberg, L.	2006	605 male juvenile offenders	Income from licit jobs, drug dealing opportunity, perceived pay-off from crime, maturity, school commitment	Self-report drug dealing frequency	Community, family and peers' factors were the strongest correlates of adolescents' frequency of drug dealing.

Table 45 (cont'd)

Rainone, G. A., et al	2006	14,977 7th-12th graders in New York	Gender, substance use, nonviolent delinquent behaviors, gang involvement	Prevalence of violence, substance use, and delinquent behaviors	Participation in youth violence is as common as other types of delinquent behaviors (e.g., theft or truancy), but not as common as alcohol and drug use.
Leah J. Floyd et al	2010	13706 black and white adolescents aged 12-17 from NSDUH	SES, substance use, availability of drugs	Sold drug in past 12 months	For White youths, substance use seems to be more relevant to drug dealing
Kerry M. Green, Elaine E. Doherty et al	2010	Community cohort of 702 urban African Americans	Heavy adolescent marijuana use. Other matching variables include sex, socioeconomic status, school adaptation/ achievement, other substance use, and delinquency.	Adult criminal involvement	30.4% of heavy users engaged in drug dealing compared to 12.3% of light/non-users.
Shook, J. J., Vaughn, M. et al	2011	227 youthful offenders	Substance use, mental health, trauma, and treatment; self-report of delinquency, peer use of substances	Drug selling (marijuana, hard drugs, prescription drugs)	70% youth in this sample involved drug dealing, the motivation not just economic but also link to substance use. The severity of youth drug dealers' risky behavior based on type of drug sold.

Table 45 (cont'd)

Shook, J. J., Vaughn, M. G	2013	3080 youth age 12-17	Indicators for use of illicit substance, delinquent and violent behavior	Past year drug selling	Most of dealers use alcohol, tobacco, and marijuana.
Gordon, R. A., Rowe, H. L	2014	930 youth from Pittsburgh Youth Study across 10 study waves	Self-reports of gang membership, reading score, peers' behavior,	Self-report drug dealing frequency	Increase in drug selling associated with gang membership, and muti-type delinquency share similar contextual risks.
Vaughn, M. G., Salas-Wright, C. P. et al	2015	5373 young adult age 18-25	Recent history of arrest, substance abuse, illicit drug use	Self-reported past year drug-selling	Young adult drug sellers reported higher levels of criminal justice involvement, substance abuse, and illicit substance use.

Table 45 (cont'd)

Hoy, C., Barker, B., et al	2016	1172 youth	Incarceration, demographic information any injection and non-injection of illegal drugs being a recent victim of violence, physical/sexual abuse	Initiation into drug dealing	Experience of recent incarceration does not appear to significantly drive youth to initiate drug dealing. However, the initiation of drug dealing was found to coincide with an elevated risk for incarceration.
Vaughn, M. G	2018	233,435 US youth aged 12-17	Gender, age, school enrollment, father's presence in the home	Self-reported past year drug-selling	The prevalence of past-year drug selling declining significantly.
Wojciechowski, T	2020	1354 juvenile offenders aged 14-18 at baseline enrollment	Individuals' resistance to peer influence, job opportunities, parental monitoring, marijuana use at age 16	Marijuana dealing frequency	Marijuana users are more likely to become dealers.

REFERENCES

REFERENCES

Altschuler, D. M., & Brounstein, P. J. (1991). Patterns of Drug Use, Drug Trafficking, and Other Delinquency Among Inner-City Adolescent Males in Washington, D.C. *Criminology*, *29*(4), 589–622. https://doi.org/10.1111/j.1745-9125.1991.tb01081.x

Beaver, K. M., & Barnes, J. C. (2012). Admission of Drug-Selling Behaviors is Structured by Genetic and Nonshared Environmental Factors: Results from a Longitudinal Twin-Based Study. *Addictive Behaviors*, *37*(6), 697–702. https://doi.org/10.1016/j.addbeh.2012.02.005

Caulkins, J. P., & Chandler, S. (2006). Long-run trends in incarceration of drug offenders in the United States. *Crime and Delinquency*, *52*(4), 619–641. https://doi.org/10.1177/0011128705284793

Chein, I., Gerard, D. L., Lee, R. S., & Rosenfeld, E. (1964). The road to H.: Narcotics, delinquency, and social policy. In *The road to H.: Narcotics, delinquency, and social policy*. Basic Books.

Cheng, H. G., Cantave, M. D., & Anthony, J. C. (2016). Alcohol Experiences Viewed Mutoscopically: Newly Incident Drinking of Twelve- to Twenty-Five- Year-Olds in the United States, 2002–2013. *Journal of Studies on Alcohol and Drugs*, *77*(3), 405. https://doi.org/10.15288/JSAD.2016.77.405

Comstock, G. W. (2001). Cohort analysis: W.H. Frost's contributions to the epidemiology of tuberculosis and chronic disease. *Sozial- Und Praventivmedizin*, *46*(1), 7–12. https://doi.org/10.1007/BF01318793

Deming, Y., Dumitrescu, L., Barnes, L. L., Thambisetty, M., Kunkle, B., Gifford, K. A., Bush, W. S., Chibnik, L. B., Mukherjee, S., De Jager, P. L., Kukull, W., Huentelman, M., Crane, P. K., Resnick, S. M., Keene, C. D., Montine, T. J., Schellenberg, G. D., Haines, J. L., Zetterberg, H., … Hohman, T. J. (2018). Sex-specific genetic predictors of Alzheimer's disease biomarkers. *Acta Neuropathologica*, *136*(6), 857–872. https://doi.org/10.1007/s00401-018-1881-4

DerSimonian, R., & Laird, N. (1986). Meta-analysis in clinical trials. *Controlled Clinical Trials*, *7*(3), 177–188. https://doi.org/10.1016/0197-2456(86)90046-2

Dunham, R. G., & Lobos, A. M. (2015). *Delinquency and Drug Use in the US BT - New Approaches to Drug Policies: A Time for Change* (M. W. Brienen & J. D. Rosen (eds.); pp. 102–120). Palgrave Macmillan UK. https://doi.org/10.1057/9781137450999_7

Fagan J, C. K. (1990). No Title. *Violence as Regulation and Social Control in the Distribution of Crack. NIDA Res Monogr.*, 103:8-43.

Floyd, L. J., Alexandre, P. K., Hedden, S. L., Lawson, A. L., Latimer, W. W., & Giles, N. (2010). Adolescent drug dealing and race/ethnicity: A population-based study of the differential impact of substance use on involvement in drug trade. *American Journal of Drug and Alcohol Abuse*, *36*(2), 87–91. https://doi.org/10.3109/00952991003587469

Frost, W. H. (1995). The age selection of mortality from tuberculosis in successive decades. 1939. *American Journal of Epidemiology*, *141*(1), 4–9. https://doi.org/10.1093/OXFORDJOURNALS.AJE.A117343

FROST, W. H. (1939). THE AGE SELECTION OF MORTALITY FROM TUBERCULOSIS IN SUCCESSIVE DECADES. *American Journal of Epidemiology*, *30-Section*(3), 91–96. https://doi.org/10.1093/oxfordjournals.aje.a118570

Gordon, R. A., Rowe, H. L., Pardini, D., Loeber, R., White, H. R., & Farrington, D. P. (2014). Serious Delinquency and Gang Participation: Combining and Specializing in Drug Selling, Theft, and Violence. *Journal of Research on Adolescence*, *24*(2), 235–251. https://doi.org/10.1111/JORA.12124

Greenland, S., Senn, S. J., Rothman, K. J., Carlin, J. B., Poole, C., Goodman, S. N., & Altman, D. G. (2016). Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations. *European Journal of Epidemiology*, *31*(4), 337–350. https://doi.org/10.1007/s10654-016-0149-3

Hasin, D. S., Saha, T. D., Kerridge, B. T., Goldstein, R. B., Chou, S. P., Zhang, H., Jung, J., Pickering, R. P., Ruan, J., Smith, S. M., Huang, B., & Grant, B. F. (2015). Prevalence of marijuana use disorders in the United States between 2001-2002 and 2012-2013. *JAMA Psychiatry*, *72*(12), 1235–1242. https://doi.org/10.1001/jamapsychiatry.2015.1858

Heeringa, S., West, B., & Berglund, P. (2017). *Applied Survey Data Analysis* (2nd ed.). CRC Press.

Hepburn, K., Barker, B., Nguyen, P., Dong, H., Wood, E., Kerr, T., & DeBeck, K. (2016). Initiation of drug dealing among a prospective cohort of street-involved youth. *Https://Doi.Org/10.1080/00952990.2016.1186684*, *42*(5), 507–512. https://doi.org/10.1080/00952990.2016.1186684

Hoy, C., Barker, B., Regan, J., Dong, H., Richardson, L., Kerr, T., & DeBeck, K. (2016). Elevated risk of incarceration among street-involved youth who initiate drug dealing. *Harm Reduction Journal*, *13*(1), 1–8. https://doi.org/10.1186/s12954-016-0120-3

Johnson, R. M., Fairman, B., Gilreath, T., Xuan, Z., Rothman, E. F., Parnham, T., & Furr-Holden, C. D. M. (2015). Past 15-year trends in adolescent marijuana use: Differences by race/ethnicity and sex. *Drug and Alcohol Dependence*, *155*, 8–15. https://doi.org/10.1016/j.drugalcdep.2015.08.025

Kagan, J. P. M. and D. V. (1984). Society and Medication: Conflicting Signals for Prescribers

and Patients. By J. P. Morgan and D. V. Kagan. (Pp. 380; illustrated; £27.00.) Lexington Books: Aldershot. 1983. *Psychological Medicine*, *14*(3), 719. https://doi.org/DOI: 10.1017/S0033291700015592

Korf, D. J., Brochu, S., Benschop, A., Harrison, L. D., & Erickson, P. G. (2008). Teen Drug Sellers—An International Study of Segregated Drug Markets and Related Violence. *Contemporary Drug Problems*, *35*(1), 153–176. https://doi.org/10.1177/009145090803500107

Levitt, S., & Venkatesh, S. (2000). An Economic Analysis of Drug-Selling Gang's Finances. *The Quarterly Journal of Economics*, *115*, 755–789. https://doi.org/10.1162/003355300554908

Li, X., & Feigelman, S. (1994). Recent and Intended Drug Trafficking Among Male and Female Urban African-American Early Adolescents. *Pediatrics*, *93*(6).

Li, X., Feigelman, S., Stanton, B., Galbraith, J., & Huang, W. (1998). Drug trafficking and drug use among urban African-American adolescents: A causal analysis. *Journal of Adolescent Health*, *23*(5), 280–288. https://doi.org/10.1016/S1054-139X(98)00021-4

Little, M., & Steinberg, L. (2006). Psychosocial correlates of adolescent drug dealing in the Inner City: Potential roles of opportunity, conventional commitments, and maturity. *Journal of Research in Crime and Delinquency*, *43*(4), 357–386. https://doi.org/10.1177/0022427806291260

Luntz, W. N. G. R. (1944). Medical Research. *British Medical Journal*, *1*(4346), 572. https://doi.org/10.1136/bmj.1.4346.572-a

Morris, J. N. (1964). *Uses of Epidemiology*. E. & S. Livingstone, 1964. http://catalog.lib.msu.edu/record=b1397398~S39a

Rainone, G. A., Schmeidler, J. W., Frank, B., & Smith, R. B. (2006). Violent Behavior, Substance Use, and Other Delinquent Behaviors among Middle and High School Students. *Youth Violence and Juvenile Justice*, *4*(3), 247–265. https://doi.org/10.1177/1541204006290154

Rott, K. W., Lin, L., Hodges, J. S., Siegel, L., Shi, A., Chen, Y., & Chu, H. (2021). Bayesian meta-analysis using SAS PROC BGLIMM. *Research Synthesis Methods*, *12*(6), 692–700. https://doi.org/https://doi.org/10.1002/jrsm.1513

Salas-Wright, C. P., Oh, S., Goings, T. C., & Vaughn, M. G. (2017). Trends in perceived access to marijuana among adolescents in the United States: 2002-2015. *Journal of Studies on Alcohol and Drugs*, *78*(5), 771–780. https://doi.org/10.15288/JSAD.2017.78.771

Saner, H., MacCoun, R., & Reuter, P. (1995). On the ubiquity of drug selling among youthful offenders in Washington, D.C., 1985-1991: Age, period, or cohort effect? *Journal of Quantitative Criminology*, *11*(4), 337–362. https://doi.org/10.1007/BF02630568

Seedall, R. B., & Anthony, J. C. (2015). Monitoring by Parents and Hypothesized Male-Female Differences in Evidence from a Nationally Representative Cohort Re-sampled from Age 12 to 17 Years: An Exploratory Study Using a “Mutoscope” Approach. *Prevention Science : The Official Journal of the Society for Prevention Research*, *16*(5), 696–706. https://doi.org/10.1007/S11121-014-0517-8

Shook, J. J., Vaughn, M. G., & Salas-Wright, C. P. (2013). Exploring the Variation in Drug Selling Among Adolescents in the United States. *Journal of Criminal Justice*, *41*(6), 365–374. https://doi.org/10.1016/j.jcrimjus.2013.07.008

Shook, J. J., Vaughn, M., Goodkind, S., & Johnson, H. (2011). An empirical portrait of youthful offenders who sell drugs. *Journal of Criminal Justice*, *39*(3), 224–231. https://doi.org/10.1016/j.jcrimjus.2011.02.014

Stanton, B., & Galbraith, J. (1994). Drug Trafficking Among African-American Early Adolescents: Prevalence, Consequences, and Associated Behaviors and Beliefs. *Pediatrics*, *93*(6).

Steinman, K. J. (2005). Drug selling among high school students: Related risk behaviors and psychosocial characteristics. *Journal of Adolescent Health*, *36*(1), 71.e1-71.e8. https://doi.org/10.1016/J.JADOHEALTH.2003.12.012

Substance Abuse and Mental Health Services Administration. (2021). *NSDUH 2019 Methodological Resource Book*. https://www.samhsa.gov/data/report/nsduh-2019-methodological-resource-book-mrb

United States. (2017). *Youth involved with the juvenile justice system*. https://youth.gov/youth-topics/juvenile-justice/youth-involved-juvenile-justice-system

Vaughn, M. G., Salas-Wright, C. P., Delisi, M., Shook, J. J., & Terzis, L. (2015). A typology of drug selling among young adults in the United States. *Substance Use and Misuse*, *50*(3), 403–413. https://doi.org/10.3109/10826084.2014.984850

Wilson, J. J., Howell, J. C., & Ph, D. (1993). *Program Rationale The Juvenile Justice System Family Influen*.

Windle, J., Moyle, L., & Coomber, R. (2020). ‘Vulnerable’ Kids Going Country: Children and Young People’s Involvement in County Lines Drug Dealing. *Youth Justice*, *20*(1–2), 64–78. https://doi.org/10.1177/1473225420902840

Wojciechowski, T. (2020). The Development of Marijuana Dealing Behavior During Adolescence and Early Adulthood Among Juvenile Offenders: Risk Factors for Development. *Deviant Behavior*, *41*(11), 1370–1382. https://doi.org/10.1080/01639625.2019.1615603