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Cigarette smoking, prescription opioid use and misuse among young adults: An exploratory analysis

Alexa R. Romberg*, Erin J. Miller Lo, Alexis A. Barton, Haijun Xiao, Donna M. Vallone, Elizabeth C. Hair

Schroeder Institute at Truth Initiative, 900 G St. NW, Washington, DC, USA

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ABSTRACT

Young adults have the highest prevalence of misuse of prescription opioids. In 2016, 7.1% of 18- to 25-year-olds reported misuse, meaning use other than as prescribed. While smoking is known to be associated with opioid use, to our knowledge no study has examined the relationships between smoking, prescribed use of opioids, and opioid misuse in young adults at the population level. Online survey data were collected in spring 2018 from a nationally representative sample of 18–25-year-olds from the Truth Longitudinal Cohort (N = 10,502). Respondents self-reported cigarette smoking, and both lifetime and recent (past 6-month) prescribed use and misuse of opioids. Generalized ordered logistic regression modeling was used to determine associations between cigarette smoking and recent prescribed use and misuse while controlling for demographic characteristics, other substance use, sensation seeking, and mental health status. Overall, 61.0% of respondents reported lifetime prescribed use of opioids and 16% reported recent prescribed use. Lifetime misuse was reported by 19.4%, with 7.8% reporting recent misuse. Together, the models revealed a graded relationship, with current smokers having higher odds of both prescribed use and misuse, never smokers having lowest odds of use or misuse, and ever smokers, those who had smoked but not in the past 30 days, falling between current and never smokers. Findings indicate a clear association between smoking and use of opioids even after accounting for a strong association between prescribed use and misuse among young adults.

1. Introduction

The United States is currently experiencing a crisis of opioid misuse, dependence and overdose. Young adults aged 18 to 25 are particularly affected by the opioid crisis. This age group has the highest prevalence of misuse, or use of prescription opioids in any way other than as prescribed by a doctor (e.g., using without a prescription, using more than prescribed, or using beyond the original prescription). In 2016, 7.1% of 18- to 25-year-olds reported misuse of opioids (Centers for Disease Control and Prevention, 2018). Young people also had the greatest percentage increase, 28%, in drug overdose deaths from 2015 to 2016 (Hedegaard et al., 2017).

Prescription opioids have contributed to the opioid epidemic: these drugs are involved in > 40% of overdose deaths in the United States and have been involved in > 200,000 overdose deaths from 1999 to 2016 (Hedegaard et al., 2017; Seth et al., 2018). Furthermore, using opioids as prescribed by a doctor has been identified as a significant risk factor for opioid misuse and dependence (Alexander et al., 2012; Bohnert et al., 2011; Edlund et al., 2014). Legitimate prescribed use often precedes misuse among adolescents, and increases the risk of future misuse among otherwise low-risk adolescents (Miech et al., 2015). In 2017, over 3 million young adults between age 18 and 25 filled at least one opioid prescription (Centers for Disease Control and Prevention, 2018).

Young or emerging adulthood is often characterized by experimentation with risky behaviors (Villanti et al., 2018). While prevalence of cigarette smoking among young adults is at historic lows, with 10.4% of young adults aged 18 to 24 reporting current cigarette use in 2017 (Wang et al., 2018), young adulthood is when initiation is most likely to occur (Cantrell et al., 2018a) and tobacco use remains a pressing public health concern.

Associations between smoking and opioid use, misuse and dependence have been documented for decades. For example, adult pain patients who smoke, including those with chronic pain, are more likely to receive opioid treatment than those who do not smoke, and may be prescribed higher doses (Ekholm et al., 2009; Fishbain et al., 2012).

* Corresponding author.
E-mail addresses: aromberg@truthinitiative.org (A.R. Romberg), elo@truthinitiative.org (E.J. Miller Lo), abarton@truthinitiative.org (A.A. Barton), jxiao@truthinitiative.org (H. Xiao), dvallone@truthinitiative.org (D.M. Vallone), ehair@truthinitiative.org (E.C. Hair).

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Smoking prevalence is exceptionally high among those in treatment for opioid use disorder, with reports ranging from 79 to 98% (Chun et al., 2009; Guydish et al., 2011). Conversely, quitting smoking is associated with higher rates of abstinence from opioids among those in addiction treatment and in recovery (Prochaska et al., 2004). Population level studies have also documented associations between smoking and prescription opioids. Nationally representative data from the United States indicate that daily and intermittent adult smokers are more than three times more likely to misuse prescription opioids than never smokers (Zale et al., 2014). The association between cigarette smoking and opioid misuse was found to be stronger for those who began smoking before the age of 18 (Zale et al., 2014). Further, among adult smokers, opioid dependence is associated with higher nicotine dependence (Parker et al., 2018) and persistence of nicotine dependence over time (Goodwin et al., 2014). Multiple studies from Norway found that, for both adolescents and adults, daily smoking was associated with higher numbers of opioid prescriptions over time (Log et al., 2011; Skurtveit et al., 2010).

Despite the significant current public health costs of both opioid misuse and cigarette smoking, to our knowledge there has not been a study that has directly examined the co-use of cigarette smoking and prescription opioids among young adults. The specific aim of this study was to examine whether, and to what extent, smoking is associated with either prescribed use or misuse of prescription opioids using a large, nationally representative sample of young adults collected in the spring of 2018. Youth who have experimented with one drug are more likely to have tried others and vulnerable characteristics such as poverty or mental health problems increase susceptibility to all drug use. Thus, to isolate the relationship between smoking and opioid use and misuse as much as possible, the analyses control for demographic characteristics, other substance use and mental health. This study examines two specific hypotheses: 1) Young people who smoke are more likely to have been prescribed opioids and to have had a greater number of prescriptions than nonsmokers; and 2) young people who smoke are more likely to have misused opioids and to have misused more frequently than nonsmokers.

2. Methods

2.1. Sample

Data were drawn from the Truth Longitudinal Cohort (TLC), a nationally representative sample of youth and young adults (ages 18–25, N = 9633). The TLC is a probability-based cohort, recruited primarily through address-based sampling with seven waves of data collection from wave 1 in April 2014 to wave 7 in February 2018. Follow-up response rates ranged from 62% to 72% of the baseline sample. Surveys included a broad set of items to capture tobacco-related knowledge, attitudes, beliefs and behavior. This analysis used data from wave 7, collected from February to May 2018, which included measures of opioid-related knowledge, attitudes, beliefs, and behavior. The study protocol was approved by Advarra Institutional Review Board (formerly Chesapeake IRB). Additional details of the TLC methods have been published elsewhere (Cantrell et al., 2018b).

2.2. Measures

2.2.1. Prescription opioid use

The questions about prior prescribed use of opioids were preceded by the following information: “The next several questions will reference prescription painkillers. By prescription painkiller, we mean any opioid/narcotic drug that may be prescribed by a doctor to relieve pain. Some examples: oxycodone (Oxycontin, Percocet, Percodan, Roxicet, Roxicodone), hydrocodone (Vicodin, Lortab, Norco, Zohydro ER), acetaminophen/aspirin with codeine (Tylenol/Fiorinal with Codeine), meperidine (Demerol), hydromorphone (Exalgo), tramadol (Ultram, Ryzolt, ConZip), oxymorphone (Opana).”

Prescribed use of opioids was measured with the following items, with lifetime use measured by “in your lifetime” and recent use by “in the past 6 months.” “On how many occasions (if any) in your lifetime / in the past 6 months have you taken prescription opioids because a doctor specifically prescribed them to you? Count each prescription as one occasion.” Lifetime/recent *misuse* of prescription opioids was measured with the items “On how many occasions (if any) in your lifetime/in the past 6 months have you taken prescription opioids without a doctor specifically prescribing them to you?” Response options for both prescribed use and misuse were 0 occasions, 1 occasion, 2 occasions, 3–5 occasions, More than 5 occasions. Recent use was only asked of respondents who indicated lifetime use.

2.2.2. Cigarette use

Ever use of cigarettes was measured with the item “Have you ever tried cigarette smoking (even 1 or 2 puffs)? (Yes/No). Those who responded Yes were then asked about current use with the item “During the past 30 days, on how many days did you smoke cigarettes (even 1 or 2 puffs)?” with possible responses ranging from 0 to 30. The Cigarette Use variable was created by combining ever and current use of cigarettes into a single variable with levels Current Use (past 30-day use), Ever Use (no past 30-day use), Never Use.

2.2.3. Covariates

Two substance use covariates were included to account for the fact that the same individuals tend to experiment with or use more than one substance. The focus of the TLC is tobacco use, so available information on other substances was limited to marijuana and binge drinking. Marijuana use was measured with the item “Have you ever used marijuana, for example; grass or pot, in your lifetime?” (Yes/No) Binge drinking was measured with the item “In the past 30 days, on how many days did you have 5 or more drinks on an occasion?” with responses 0–30, which was collapsed to a binary variable indicating any binge drinking. The following mental health covariates were included to account for the fact those with poorer mental health are at higher risk of substance use (Armstrong and Costello, 2002; Sullivan et al., 2006). Internalizing mental health was measured using two items from the National Longitudinal Survey of Youth 1997 (U.S. Department of Labor, 2015) indicating past 6-month frequency of sleep trouble and depressed mood. Responses were averaged to form a single score that ranged from 0 to 3. Generalized anxiety was measured with the 2-Item Generalized Anxiety Disorder Scale (Kroenke et al., 2007). Responses were averaged to form a single score that ranged from 0 to 6 and dichotomized to Lower Anxiety < 3 and Higher Anxiety ≥ 3. Sensation seeking was measured with the 8-item Brief Sensation Seeking Scale (Hoyle et al., 2002). Responses were averaged to form a single measure ranging from 1 to 5. Sensation seeking was measured at study entry for each respondent. For those whose first observation was Wave 7, sensation seeking was measured contemporaneously as the substance use and mental health items. However, for those that entered the study in Waves 1–6, this measure was collected between 1 and 3.5 years prior to the substance use and mental health measures. Evidence suggests that sensation seeking characteristics are relatively stable over time (Pedersen, 1991).

2.2.4. Demographics

Demographic predictors included participant age (in years), gender (male/female), parent education (Less than high school/High school graduate/Some college/Associate's Degree/College graduate); subjective financial situation (Live comfortably/Meets expenses with a little leftover/Just meets needs/Does not meet needs (Williams et al., 2017) and highest education attained (High school degree or less, More than high school).

3. Analysis plan

Responses were weighted to account for survey design and response rate and to align the data with the Current Population Survey with respect to age, gender and race/ethnicity. We reported raw frequency counts and weighted percentages and all modeling was done with weighted data.

Recent occasions of prescribed use and misuse were used as outcomes for separate models. Each of the outcome measures was collapsed to 3 levels: 0 occasions, 1 occasion, and 2 or more occasions. Those who reported no lifetime use were coded as "0 occasions."

The data were modeled using generalized ordered logistic models, also known as partial proportional odds models. This modeling framework tests for effects of predictors in a series of binary logistic comparisons that test the cumulative response probability along the ordered dimension. For our three-level outcomes, the first comparison tests participants' relative odds of responding any number of occasions compared to "0 occasions." The second comparison tests participants' relative odds of responding "2 or more occasions" relative to one or no occasions. These comparisons enabled us to explicitly test two hypotheses 1) whether smoking is associated with higher odds of any prescribed use/misuse of prescription opioids (the first binary comparison), and 2) whether smoking is associated with higher odds of multiple occasions of prescribed use/misuse (the second binary comparison). We used the autofit function in the gologit2 package in Stata to test, for each model, whether the effect of each predictor was the same for both comparisons (i.e., that the proportional odds assumption held) using an alpha of $p < .025$ (Williams, 2006). When effects were the same, we reported one odds ratio in the text and tables. When effects were different, we reported separate odds ratios for each comparison. We conducted Type III tests for all variables and only report as significant effects for which both the Type III test and the individual comparison were below the alpha of 0.05.

We examined both unadjusted models including only smoking as a predictor of prescribed use/misuse and models adjusted for all demographic, sensation seeking, mental health and other substance use covariates. The adjusted models also included misuse as a predictor of prescribed use and prescribed use as a predictor of misuse, to account for the fact that one type of use can lead to the other. Some participants (5.1%) were missing data for one or more covariates and were therefore excluded from the adjusted models. Individual model sample sizes are noted in Table 2.

Cigarette use was entered into all models with Ever (but not current) use as the reference group. For the prescribed use model, the misuse predictor variable was coded as a 3-level categorical variable with 0 = no occasions, 1 = any number of lifetime occasions but none in the past 6 months, and 2 = any occasions in the past 6 months. For the recent misuse model, the prescribed use predictor variable was coded in the same way. Analyses were conducted in Stata SE V.15.1 (Stata Statistical Software: Release 15, 2017). All confidence intervals reported are 95% confidence intervals.

4. Results

4.1. Study sample description

Sample demographic characteristics are presented in Table 1. Approximately half the sample was female (49%) and the average age was 21.5 years (SD = 2.2 years). The majority of respondents reported never having tried cigarette smoking (61.5%), and 26.5% reported having ever smoked a cigarette but not within the past 30 days. Approximately 12.0% of the sample were current (past 30 days) smokers.

4.2. Prevalence of prescription opioid use

The majority of respondents reported prescribed use of opioids in their lifetime (61.0%), with 6.7% reporting having received > 5 prescriptions. Recent prescribed use (i.e., in the past 6 months) was reported by 16.0%, with 9.4% of respondents reporting just one occasion of recent prescribed use and 5.6% reporting 2 or more occasions.

Lifetime misuse of prescription opioids was reported by 19.4% of respondents, with 6.6% of respondents reporting only one lifetime occasion of misuse and 4.9% reporting > 5 occasions. Recent misuse was reported by 7.8%, with 3.0% of respondents reporting just one occasion

Table 1
Sample characteristics. Frequencies and weighted percentages (or mean and SD).

		Overall (n = 10,502)	Lifetime prescription users (n = 6,734)	Lifetime misusers (n = 1,908)
Variable		No. (%)	No. (%)	No. (%)
Cigarette smoking status	*Never*	6,637 (61.5)	4,039 (57.4)	750 (37.7)
	Ever but not current	2,735 (26.5)	1,872 (28.6)	710 (36.2)
	Current	1,130 (12.0)	823 (14.0)	448 (26.1)
Age	*mean (SD)*	21.5 (2.2)	21.7 (2.2)	21.8 (2.2)
Gender	*Female*	5,995 (49.4)	4,054 (52.2)	1,129 (51.5)
	Male	4,502 (50.6)	2,677 (47.8)	778 (48.5)
Race/Ethnicity	*White*	6,839 (54.8)	4,568 (57.4)	1,081 (46.0)
	Black/African American	958 (14.3)	572 (13.4)	190 (15.1)
	Hispanic	1,544 (22.0)	940 (21.8)	427 (31.4)
	Other	1,133 (8.9)	639 (7.3)	207 (7.5)
Parental education	*Less than high school*	237 (3.0)	135 (2.6)	60 (3.9)
	High school graduate	1,352 (17.5)	806 (16.4)	316 (22.7)
	Some college/ Associate's degree	2,386 (25.0)	1,560 (25.0)	503 (27.3)
	College graduate or more	6,112 (54.6)	4,006 (56.0)	943 (46.1)
Financial situation	*Live comfortably*	3,760 (37.0)	2,331 (35.0)	549 (29.8)
	Meet needs with a little left over	4,059 (38.4)	2,663 (39.9)	768 (40.0)
	Just meet basic expenses with nothing left over	1,981 (18.4)	1,324(19.2)	406 (20.7)
	Don't meet basic expenses	662 (6.2)	398 (5.9)	179 (9.5)
Ever marijuana use	*No*	5,215 (50.8)	3,094 (46.1)	554 (29.6)
	Yes	5,246 (49.2)	3,621 (53.9)	1,342 (70.4)
Risky drinking	*No*	6,608 (65.4)	4,074 (61.9)	942 (48.8)
	Yes	3,850 (34.6)	2,637 (38.1)	958 (51.2)
Sensation-seeking	*mean (SD)*	3.0 (0.8)	3.0 (0.8)	3.2 (0.8)
Anxiety	*Low anxiety*	7,864 (76.6)	4,921 (74.3)	1,209 (64.1)
	High anxiety	2,638 (23.4)	1,813 (25.7)	699 (35.9)
Internalizing mental health	*mean (SD)*	2.3 (0.8)	2.4 (0.8)	2.6 (0.9)

Note. Frequency totals may differ from sample total due to missing data.

of recent misuse and 3.8% reporting 2 or more occasions.

4.3. Prescribed use of opioids

Cigarette Use was significantly associated with recent prescribed use of opioids (Table 2). In the unadjusted model, Current smokers had higher odds than Ever smokers for both having received any recent prescriptions and of having received 2 or more prescriptions (both OR = 1.88, CI: 1.50–2.36). The single odds ratio for both comparisons indicates that the partial proportional odds assumption of ordinal regression was satisfied. Relative to Ever Smokers, Never Smokers had lower odds of any recent prescribed use (OR = 0.77, CI: 0.65–0.91) and lower odds of 2+ occasions of prescribed use (OR = 0.52, CI: 0.41–0.66).

Cigarette use remained significantly associated with recent prescribed use of opioids in the adjusted model, though the effects were somewhat smaller. Relative to Ever smokers, Current smokers had higher odds of any recent prescribed use (OR = 1.31, CI: 1.01–1.69) and of 2+ occasions of prescribed use (OR = 1.77, CI: 1.29–2.44). Never smokers, however, were not different than Ever smokers. Recent misuse was strongly associated with recent prescribed use (both OR = 5.98, CI: 4.70–7.62), though misuse prior to the past 6-months was not significantly associated with recent prescribed use (both OR = 1.25, CI: 0.98–1.58).

Full covariate effects for both outcomes are reported in Table 2. Poorer internalizing mental health and binge drinking were associated with higher odds of recent prescribed use, as was being female. Hispanics and non-Hispanic African Americans had higher odds of recent prescribed use relative to non-Hispanic White respondents.

4.4. Prescription opioid misuse

Cigarette use was significantly associated with recent misuse of prescription opioids (Table 2). In the unadjusted model, Current

Table 2
Cigarette and opioid use effects from the generalized ordered logistic regression models.

	Recent prescribed use		Recent misuse	
	Unadjusted (n = 10,500)	Adjusted (n = 9,963)	Unadjusted (n = 10,499)	Adjusted (n = 9,963)
Cigarette use status				
Never	0.77 (0.65-0.91)[a] 0.52 (0.41-0.66)[b]	0.98 (0.79-1.21)	0.43 (0.34-0.55)	0.71 (0.54-0.94)
Ever but not current	Ref	Ref	Ref	Ref
Current	1.88 (1.50-2.36)	1.31 (1.01-1.69)[a] 1.77 (1.29-2.44)[b]	2.31 (1.76-3.04)	1.49 (1.09-2.03)
Misuse of prescription opioids (Ref = None)				
Lifetime but not past 6 months		1.25 (0.98-1.58)		
Any past 6 months		5.98 (4.70-7.62)		
Prescribed use of opioids (Ref = None)				
Lifetime but not past 6 months				1.57 (1.12-2.19)
Any past 6 months				7.18 (5.15-10.01)
Age		0.99 (0.95-1.03)		1.00 (0.95-1.06)
Gender				
Male (Ref = Female)		0.80 (0.68-0.95)		0.96 (0.77-1.21)[a] 1.19 (0.90-1.59)[b]
Race/Ethnicity				
White		Ref		Ref
Black/African American		2.09 (1.67-2.62)		1.78 (1.26-2.52)
Hispanic		1.27 (1.03-1.57)		1.87 (1.42-2.48)
Other		0.95 (0.71-1.27)		1.32 (0.92-1.90)
Highest education				
More than high school (Ref = HS degree or less)		0.86 (0.72-1.04)		0.83 (0.63-1.10) 0.63 (0.46-0.88)
Parental education				
Less than high school		Ref		Ref
High school graduate		0.96 (0.63-1.48)		0.52 (0.29-0.93)
Some college/ Associate's degree		0.73 (0.48-1.10)		0.59 (0.34-1.02)
College graduate or more		0.70 (0.47-1.06)[a] 0.54 (0.35-0.85)[b]		0.41 (0.24-0.70)
Financial situation				
Live comfortably		Ref		Ref
A little left over		1.13 (0.94-1.37)		0.95 (0.72-1.26)
Just meet basic expenses with nothing left over		1.17 (0.94-1.46)		1.04 (0.75-1.44)[a] 0.75 (0.50-1.11)[b]
Don't meet basic needs		1.20 (0.86-1.68)		1.95 (1.29-2.95)
Ever marijuana use				
Yes (Ref = No)		0.93 (0.76-1.14)		1.34 (1.02-1.76)
Binge drinking				
Yes (Ref = No)		1.29 (1.08-1.54)		1.71 (1.33-2.19)
Sensation-seeking		0.99 (0.89-1.09)		1.27 (1.09-1.48)
Anxiety				
High (Ref = Low)		1.06 (0.86-1.31)		1.82 (1.38-2.41)
Internal mental health		1.23 (1.10-1.38)[a] 1.41 (1.21-1.64)[b]		1.03 (0.88-1.21)[a] 1.23 (1.01-1.50)[b]

Note. OR = Odds Ratio; CI = 95% Confidence Interval When the proportional odds assumption held, a single OR for both binary comparisons was estimated. Otherwise, separate OR for each comparison were estimated.

[a] OR (CI) for no versus any occasions.

[b] OR (CI) for less versus more frequent occasions.

smokers had higher odds than Ever smokers of any recent misuse and of 2+ occasions of recent misuse (both OR = 2.31, CI: 1.76–3.04). Relative to Ever Smokers, Never Smokers had lower odds of misuse for both comparisons (both OR = 0.43, CI: 0.34–0.55).

Cigarette use remained significantly associated with recent misuse in the fully adjusted model, with the same pattern of effects but smaller effect sizes. Current smokers had higher odds of recent misuse (both OR = 1.49, CI: 1.09–2.03) relative to Ever smokers and Never smokers had lower odds (both OR = 0.71, CI: 0.54–0.94). Prescribed use of opioids, particularly recent prescribed use, was strongly associated with recent misuse. Relative to no lifetime prescribed use, those who had received prescriptions, but not in the past 6 months, had higher odds of recent misuse (OR = 1.57, CI: 1.12–2.19), while those who had received prescriptions in the past 6 months had a 700% increase in odds of misuse (OR = 7.18, CI: 5.15–10.01).

Most covariate predictors were associated with recent misuse in some way (Table 2). Those with higher anxiety, poorer internalizing mental health, who were more sensation seeking and those who had used marijuana or reported binge drinking each had higher odds of recent misuse. Interestingly, neither age nor gender was associated with recent misuse, though other demographic characteristics were. Relative to non-Hispanic White respondents, Hispanic and non-Hispanic Black respondents had higher odds of misuse; those respondents with more financial security, more education and more parental education had lower odds of misuse.

5. Discussion

This study reveals important and timely information about the relationships between opioid prescribed use, misuse of prescription opioids and cigarette smoking among young adults. Together, the models find a graded relationship, with current smokers having highest odds of both prescribed use and misuse, never smokers having lowest odds, and those who had smoked but not in the past 30 days falling between. These relationships between cigarette smoking and both prescribed use and misuse of opioids persisted after controlling for demographic characteristics as well as other measures associated with substance use, including marijuana use, binge drinking, sensation seeking characteristics and mental health measures (Goldberg and Cataldo, 2018; Quinn et al., 2018).

Young adulthood represents a critical time in development with respect to substance use. Increasing independence comes with opportunities to experiment with substances or to progress from experimentation to more established regular use (Villanti et al., 2018). To our knowledge, this is the first study to explicitly explore smoking and both prescribed use and misuse of prescription opioids specifically in young adults. Our findings are consistent with prior research that has examined either prescribed use (Skurtveit et al., 2010; Log et al., 2011) or misuse (Zale et al., 2014) of prescription opioids individually among adults or adolescents, or as a covariate in analyses focused on other factors (Back et al., 2010; Becker et al., 2008). A recent study using nationally representative data from U.S. middle-aged and older adults found that tobacco use was significantly associated with both prescribed use and misuse of opioids (Han et al., 2019). Findings reveal that current smoking significantly increases the odds of having received a prescription in the past 6 months, including having gotten 2 or more recent prescriptions. Additionally, consistent with prior work, we found that prescribed use of opioids was strongly associated with misuse of prescription opioids (Alexander et al., 2012; Bohnert et al., 2011; Edlund et al., 2014; McCabe et al., 2017; Miech et al., 2015).

The current cross-sectional data cannot address the potential mechanisms that might account for the elevated odds of either prescribed use or misuse among young adult smokers. It is possible that those who smoke are more open to taking prescription opioids for pain than those who do not smoke. There is also evidence for direct relationships between smoking and pain. Smokers experience more pain than nonsmokers (Ditre et al., 2011), and the association between smoking and pain is present in adolescence (Shiri et al., 2010). Several studies with adolescents have found a relationship between the *number* of cigarettes smoked and low back pain (Shiri et al., 2010), and adolescent smoking is predictive of chronic pain in young adults (Hestbaek et al., 2006). Research with adult smokers has found that pain motivates smoking, suggesting a bidirectional relationship (Ditre et al., 2011). Incorporating more detailed measures of smoking, such as age of initiation and smoking frequency, may yield additional insights into the nature of the relationship between smoking and opioid use behaviors (Zale et al., 2014). Conservatively, we included the strong association between recent prescribed use and recent misuse in both models. However, the models cannot reveal the causal direction of that association. Future work, particularly prospective longitudinal research that can examine the temporal order of smoking and opioid use behaviors, should explore the extent to which prescribed use of opioids mediates or potentially moderates the association between smoking and prescription opioid misuse.

This study has several additional limitations. First, the self-reported amount of prescribed use and misuse may reflect recall or social acceptability bias. Second, the misuse question asked about taking prescription opioids "without a doctor specifically prescribing them to you," and respondents may not have interpreted the wording to cover all forms of misuse (particularly taking more of a current prescription). Third, the study did not collect measures of pain, health, or reasons for prescribed use or misuse (such as misuse for pain relief or recreation) that might help illuminate the observed relationships between smoking and opioid use. Fourth, while we included many covariates in the adjusted models to assess the association between smoking and opioid use as specifically as possible, unmeasured confounds may account for some of the association. Last, items to identify the source of the prescription opioids misused by this population (e.g., from their own prescription or another source) were not included.

6. Conclusions

The present study found a clear association between cigarette smoking and prescribed use and misuse of prescription opioids among young adults. Future work is needed that includes more details of misuse and the timing of misuse relative to prescribed use and smoking initiation. Given the current opioid crisis and the ongoing toll of tobacco use on the public's health, it is critical to understand how cigarette smoking and opioid use behaviors, including both prescribed use and misuse, may interact to facilitate and maintain these high-risk behaviors among this vulnerable population.

Author contributions

A. Romberg conceptualized the study and the analyses. H. Xiao implemented the analyses. All authors collaborated on the interpretation of the findings and placement in context. The manuscript was drafted by A. Romberg, E. Miller Lo and A. Barton and all authors were responsible for significant revisions and refinement of the manuscript's content.

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Declaration of competing interest

The authors have no conflicts to report.

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