


E-cigarette Use Among Middle and High School Students in New York City Before and After Passage of Tobacco 21

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ABSTRACT

INTRODUCTION: Despite declines in cigarette smoking in the US, electronic cigarette (e-cigarette) use has increased among middle and high school students. In 2014, New York City (NYC) implemented Tobacco 21 (T21) to prohibit sales to anyone under age 21. Our study goal was to measure the effectiveness of T21 on e-cigarette use.

METHODS: We used the New York State (NYS) Youth Tobacco Survey—a biennial, school-based, self-administered survey. We explored middle (N = 5249) and high (N = 7296) school NYC students' (male and female) current (past 30 days') e-cigarette use from 2014 (pre-T21) to 2018 (post-T21). Results were compared with students in the rest of NYS (ROS). Bivariate and multivariable logistic regression analyses assessed correlates of e-cigarette use, beliefs about harmfulness, addictiveness, and susceptibility.

RESULTS: NYC high school students' current e-cigarette use increased from 2014 to 2018 (8.1% vs 23.5%, $P < .001$). Middle school students' use increased between 2014 (4.8%) and 2016 (9.0%) yet reversed by 2018 (5.7%) (2014 vs 2018, $P = .576$). ROS middle school (2.2% vs 7.4%, $P < .001$) and high school (12.0% vs 29.3%, $P < .001$) use increased from 2014 to 2018. Willingness to try e-cigarettes among those who had never tried an e-cigarette was twice as high (AOR = 2.19, 95% CI = 1.15–3.17) among NYC high school students in 2018 compared with 2014.

CONCLUSIONS: E-cigarette use increased among NYC high school students despite T21. T21 may have reduced use among middle school students over time. Programs that denormalize e-cigarettes and policies that further restrict access are needed to decrease youth e-cigarette use.

KEYWORDS: E-cigarette, youth, New York City, Tobacco 21

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Introduction

Electronic cigarettes (e-cigarettes) have been marketed as safe, new alternatives to conventional or traditional cigarettes (cigarettes) without sufficient evidence about long-term risks, which are particularly concerning for youth.^{1–3} E-cigarette aerosol contains some harmful chemicals, such as formaldehyde and nicotine.^{4–6} Mean nicotine concentration in products sold in the United States has increased over time, which may also increase the potential for long-term use, both among adults and youth.⁷ Exposure to nicotine during adolescence can worsen memory and concentration, impact learning ability, and cause dependence during a period of heightened susceptibility.^{8–10} Long-term e-cigarette use is also concerning for chronic exposure to toxic and carcinogenic chemicals in the aerosol, which could lead to chronic health issues.^{11–13} E-cigarette use was also recently linked to a nationwide outbreak of lung injury; although most of these lung injuries were related to use of cannabis products, a smaller proportion appeared to be due to exclusive nicotine e-cigarette use.¹⁴

Over the past decade, e-cigarettes have often been marketed as a harm reduction aid for adults who use cigarettes.^{1,2,3,15} However, a growing body of evidence shows e-cigarettes may be a starter product for cigarettes among adolescents and young adults. National, state, and local longitudinal studies show that among youth and young adults who smoke cigarettes, e-cigarette use at baseline predicts cigarette initiation at follow-up.¹⁶ Nationally, nearly 9 out of 10 cigarette smokers started before they were 18 years of age; it is therefore important to prevent youth from becoming addicted to nicotine through both cigarettes and e-cigarettes.^{17–19}

E-cigarettes have become increasingly popular among youth in the United States (US). Nationally, e-cigarette use increased among middle (.6%–4.9%) and high school students (1.5%–20.8%) from 2011 to 2018.^{20,21} More than 570,000 middle school students and three million high school students used e-cigarettes in 2018.²² One in five middle schoolers who said they had tried e-cigarettes had never smoked cigarettes.²² Beginning in 2014, e-cigarettes were more commonly used than any tobacco product among both middle and high school students.²²



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Awareness of e-cigarettes and changing social norms and perceptions are likely influenced by e-cigarette marketing. Unlike cigarette marketing, e-cigarette marketing is not closely regulated. According to national Nielsen data, youth exposure to television e-cigarette advertisements increased more than 250% between 2011 and 2013.²³ National survey data in 2014 showed there was a dose-dependent association between the number of channels of e-cigarette marketing exposure (eg, television, print media, and in-store) and likelihood of and susceptibility to use.²⁴ In 2019, data showed that most young adults and adolescents were non-smokers due to the negative social stigma cigarettes carry.²⁵ Nevertheless, e-cigarettes are a relatively new product that may not have similar negative connotations. An environment in which e-cigarette use becomes normalized could lead to higher prevalence of use.^{26,27} Previous studies show e-cigarette use is strongly associated with psychosocial factors including living with another e-cigarette user, friends' use of e-cigarettes, and a favorable reaction to e-cigarettes by participants' friends.²⁸ In 2012, national data showed half of students reported never hearing of e-cigarettes or not knowing enough about them to judge their harmfulness.²⁷ In 2013, national data showed more than three in four respondents were aware of e-cigarettes. Half of all students and 65% of current smokers believed e-cigarettes were less harmful than cigarettes.²⁸ These data suggest that social norms and perceived harmfulness surrounding e-cigarettes had rapidly shifted in a troubling direction among youth.

To protect youth from the health effects of nicotine and tobacco use, NYC passed the Tobacco 21 law (T21) which prohibits youth under the age of 21 from purchasing tobacco products and e-cigarettes.²⁹ The law went into effect on August 1, 2014. Unlike many jurisdictions which classify e-cigarettes as tobacco products, NYC defines an e-cigarette as "an electronic or battery-operated device that an aerosol or emission for inhalation. Electronic cigarette also means any refill, cartridge, any other component of an electronic cigarette and any e-liquid. Electronic cigarette shall not include any product approved by the food and drug administration for sale as a drug or medical device." While a license has always been required to sell cigarettes in NYC, a license was not required to sell e-cigarettes until August 23, 2018. Prior to this date, it was difficult to comprehensively monitor and enforce age restrictions for e-cigarette sales, potentially limiting T21's impact on this sector of the market.

The objective of this study was to examine prevalence and predictors of e-cigarette use, interest, knowledge, and attitudes among youth, and whether they changed between 2014 and 2018. To measure the effectiveness of T21 on e-cigarette use, we compared prevalence of e-cigarette use in 2014 (before the law went into effect), 2016, and 2018 in NYC. The rest of New York State (ROS), where T21 was not a statewide law until November 13, 2019, was used as a further comparison.

Methods

The Youth Tobacco Survey (YTS) was developed by the Centers for Disease Control and Prevention in partnership with

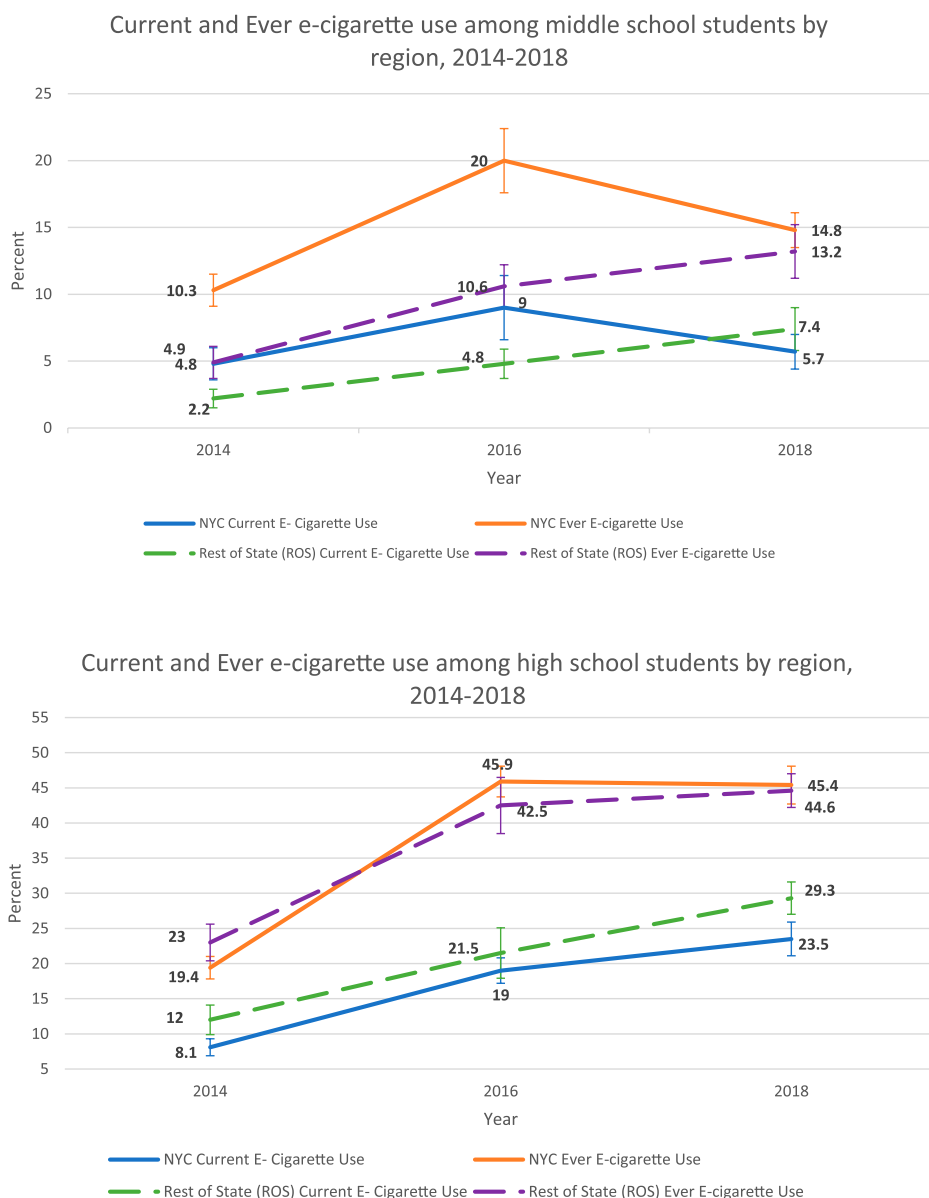
US states to provide trend surveillance of youth tobacco use, access, and perceptions.²⁸ The New York State (NYS) Department of Health has conducted the NYS YTS, modeled after the national YTS, biennially since 2000 to monitor trends and assess the aggregate effects of various interventions. The NYS YTS was designed to provide accurate estimates separately for students in NYC, for students attending schools in the ROS, and for the students in NYS as a whole.³⁰ During the spring (March, April, and May) of each year, trained field staff entered randomly selected classrooms in public and private schools from grades 6 through 12 and administered the NYS YTS.³⁰ Participating schools were offered an incentive, which amounted to \$1000 per school. Our analysis focused solely on 2014, 2016, and 2018 NYS YTS data, as survey items covering electronic cigarette items were first included in 2014. Completed surveys were weighted to represent the middle and high school enrollment population of each stratified area. All data were self-reported. This study contained only public use data and did not classify as human subjects research according to the NYC Department of Health and Mental Hygiene's institutional review board (IRB).

Measures

We compared responses across waves of the NYS YTS, stratified by public and private school grades (middle [grades 6 through 8] and high school [grades 9 through 12]) and geographic location (NYC and ROS). Our four primary outcomes regarding e-cigarettes and their associated questions were (1) current e-cigarette use: "During the past 30 days, on how many days did you use electronic cigarettes or e-cigarettes such as blu, 21st Century Smoke, or NJOY?" (2) perceived relative harmfulness: "Do you believe that e-cigarettes are more or less harmful than regular cigarettes?" (3) perceived relative addictiveness: "Do you believe that e-cigarettes are more or less addictive than regular cigarettes?" and (4) willingness to try an electronic cigarette or e-cigarette anytime in the next year (among those who never tried an e-cigarette): "Do you think you will try an e-cigarette any time in the next year?"

In addition, e-cigarette susceptibility was assessed using the following questions: "Do you think you will try an electronic cigarette or e-cigarette soon?" and "If one of your best friends were to offer you an e-cig, would you use it?"

E-cigarette knowledge and attitudes of students were assessed using questions regarding harmfulness, addictiveness, and whether young people looked cool using e-cigarettes. Familiarity with e-cigarette advertising was assessed using the questions: "When you go to a (convenience store) (supermarket) (gas station) (pharmacy/drug store), how often do you see ads for e-cigarettes or items that have e-cigarette company names or pictures on them?"; "When you watch TV or go to the movies, how often do you see ads or promotions for electronic cigarettes or e-cigarettes?" We collapsed "All of the time" and "most of the time" categories and the "hardly ever/never" and "never"



**Error bars represent 95% confidence intervals

Figure 1. Current and Ever e-cigarette use among middle and High school students by region, 2014-2018.

categories. Other e-cigarette and smoking variables were analyzed using the questions: “Have you ever tried an electronic cigarette or e-cigarette such as blu, 21st Century Smoke or NJOY?” (ever e-cigarette use), “During the past 30 days, on how many days did you smoke cigarettes?” (current cigarette smoking was one or more days of use in the past 30), and “How many of your four closest friends smoke cigarettes?” (friends who smoke).

Demographics

NYC and ROS demographic characteristics were examined separately. Both groups included categorical variables: sex (male/female) and race/ethnicity (White non-Latino, Black

non-Latino, Latino, Asian non-Latino, and other non-Latino).

Statistical analysis

Analyses were conducted using survey procedures in SAS version 9.4. Weighted population, prevalence estimates, and 95% confidence intervals (CIs) were calculated for all variables of interest. Bivariate analyses of variables of interest were compared by survey year using t-tests. Multivariable logistic regression analyses, including adjusted odds ratios (AORs) and 95% CIs were performed for the four primary outcomes. Models were adjusted for year, sex, race/ethnicity, friends who smoke, current cigarette smoking, current e-cigarette use, perceived

Table 1. Current, ever e-cigarette current use among NYC students, by grade level, 2014-2018.

NEW YORK CITY (NYC)											
ALL PARTICIPANTS											
MIDDLE SCHOOL (GRADES 6 THROUGH 8)						HIGH SCHOOL (GRADES 9 THROUGH 12)					
	2014 (N = 2118)	2016 (N = 1601)	2018 (N = 1530)	2014 VS 2016 P-VALUE	2014 VS 2018 P-VALUE	2014 (N = 2610)	2016 (N = 2380)	2018 (N = 2306)	2014 VS 2016 P-VALUE	2014 VS 2018 P-VALUE	
%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)
Current e-cigarette use											
Yes	4.8 (3.7, 6.1)	9.0 (6.9, 11.7)	5.7 (4.5, 7.3)	0.018	0.576	8.1 (7.0, 9.4)	19.0 (17.3, 20.9)	23.5 (21.2, 26.0)	< .0001	< 0.001	
Ever e-cigarette user											
Yes	10.3 (8.7, 12.1)	20.0 (17.4, 22.9)	14.8 (12.8, 17.0)	0.008	0.209	19.4 (17.8, 21.1)	45.9 (43.7, 48.2)	45.4 (42.7, 48.1)	< 0.001	< 0.001	
Current cigarette smoking											
Yes	11 (0.7, 1.5)	1.0 (0.6, 1.8)	0.9 ^a (0.5, 1.8)	0.964	0.778	5.5 (4.5, 6.5)	4.1 (3.3, 5.1)	3.5 (2.7, 4.7)	0.248	0.189	
Current middle school e-cig users						Current high school e-cig users					
2014 (N = 110)	2016 (N = 119)	2018 (N = 83)	2014 vs 2016 P-value	2014 vs 2018 P-value	2014 (N = 143)	2016 (N = 143)	2018 (N = 383)	2018 (N = 474)	2014 vs 2016 P-value	2014 vs 2018 P-value	
%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)
Gender											
Female	5.3 (3.6, 7.5)	8.3 (6.2, 11.1)	6.2 (4.5, 8.3)	0.110	0.658	6.2 (4.9, 7.8)	22.0 (19.5, 24.8)	23.9 (20.8, 27.4)	< .001	< 0.001	
Male	4.3 (3.0, 6.2)	9.8 (6.4, 14.7)	4.8 (3.1, 7.4)	0.057	0.798	10.4 (8.5, 12.7)	14.5 (12.3, 17.1)	22.7 (19.3, 26.5)	0.038	< 0.001	
Race/Ethnicity											
White, non-Latino	5.5 (2.8, 10.3)	2.7 (1.3, 5.7)	4.6 (2.5, 8.0)	0.325	0.835	6.7 (4.6, 9.6)	17.0 (12.2, 23.2)	27.9 (23.0, 33.3)	0.045	< 0.001	
Black, non-Latino	5.6 (3.4, 9.3)	11.4 (5.5, 22.4)	3.9 (2.3, 6.4)	0.266	0.678	5.2 (3.7, 7.4)	11.6 (9.1, 14.7)	12.6 (8.8, 17.8)	0.003	0.003	
Latino	4.9 (3.3, 7.1)	12.1 (9.4, 15.6)	7.4 (4.9, 11.1)	0.011	0.255	10.7 (8.5, 13.4)	25.4 (22.5, 28.6)	34.1 (29.5, 39.1)	< 0.001	< 0.001	

(Continued)

Table 1. Continued.

NEW YORK CITY (NYC)												
ALL PARTICIPANTS												
MIDDLE SCHOOL (GRADES 6 THROUGH 8)				HIGH SCHOOL (GRADES 9 THROUGH 12)								
	2014 (N = 2118)	2016 (N = 1601)	2018 (N = 1530)	2014 VS 2016 P-VALUE	2014 VS 2018 P-VALUE	2014 (N = 2610)	2016 (N = 2380)	2018 (N = 2306)	2014 VS 2016 P-VALUE	2014 VS 2018 P-VALUE		
%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	
Asian, non-Latino	1.4 (0.7, 2.8)	5.4 (2.9, 9.7)	4.6 ^a (1.5, 13.0)	0.025	0.244	5.0 (3.2, 7.8)	9.2 (6.4, 13.0)	12.0 (9.0, 15.7)	0.041	0.013		
Other, non-Latino	10.7 (4.9, 21.8)	9.7 (3.6, 23.5)	10.0 ^a (3.4, 25.7)	0.857	0.992	12.4 (6.9, 21.5)	24.8 (12.0, 44.3)	29.6 ^a (14.5, 51.1)	0.091	0.040		
Current cigarette smoking												
Yes	62.1 (40.8, 79.5)	84.6 ^a (60.1, 95.3)	89.2 ^a (49.4, 98.6)	0.181	0.101	44.7 (34.1, 55.7)	66.2 ^a (54.6, 76.1)	77.4 ^a (59.3, 89.0)	0.008	0.008		
Friends who smoke cigarettes												
None	1.5 (0.9, 2.4)	5.1 (3.3, 7.8)	3.4 (2.4, 4.7)	0.019	0.085	3.0 (2.2, 4.2)	14.5 (12.6, 16.6)	17.8 (15.3, 20.8)	< 0.001	< 0.001		
1 or more	20.6 (14.7, 28.0)	33.2 ^a (23.0, 45.2)	17.6 (10.4, 28.4)	0.060	0.662	17.9 (14.8, 21.6)	36.2 (31.1, 41.6)	48.7 (42.0, 55.3)	< 0.001	< 0.001		
Not sure	8.7 (3.7, 18.9)	11.1 ^a (5.8, 20.1)	10.3 ^a (5.3, 19.0)	0.616	0.710	10.3 (6.7, 15.6)	17.1 (11.7, 24.2)	17.1 (12.0, 23.7)	0.080	0.081		

Bold means statically significant ($P < 0.05$).
^aEstimate should be interpreted with caution. Estimate's relative standard error (a measure of estimate precision) is greater than 30% or the sample size is less than 50, making the estimate potentially unreliable. Data are suppressed due to imprecise and unreliable estimates.
 Confidence intervals (CIs) are a measure of estimate precision: the wider the CI, the more imprecise the estimate.

Table 2. Knowledge and attitudes among those who never tried e-cigarettes and all participants, by grade level, 2014-2018.

NEW YORK CITY (NYC)										
AMONG THOSE WHO NEVER TRIED E-CIGARETTES										
	MIDDLE SCHOOL (GRADES 6 THROUGH 8)					HIGH SCHOOL (GRADES 9 THROUGH 12)				
	2014 (N = 1173)		2018 (N = 1230)		2014 VS 2018 P- VALUE	2014 (N = 1894)		2018 (N = 1289)		2014 VS 2018 P- VALUE
	%	(95% CI)	%	(95% CI)		%	(95% CI)	%	(95% CI)	
Do you think you will try an electronic cigarette or e-cigarette soon?										
Yes	3.3	(2.3, 4.8)	4.0	(3.0, 5.3)	0.596	6.8	(5.7, 8.1)	7.4	(5.8, 8.1)	0.574
Do you think you will try an electronic cigarette or e-cigarette any time in the next year?										
Yes	2.0	(1.2, 3.4)	2.6	(1.7, 4.1)	0.465	5.3	(4.3, 6.5)	6.8	(5.2, 8.8)	0.102
If one of your best friends were to offer you an e-cig, would you use it?										
Yes	3.6	(2.5, 5.3)	4.2	(2.9, 5.9)	0.701	8.1	(6.9, 9.6)	7.6	(6.0, 9.7)	0.657
Among all students										
Middle school (grades 6 through 8)										
High school (grades 9 through 12)										
	2014 (N = 2118)		2018 (N = 1530)		2014 vs 2018 P-value	2014 (N = 2610)		2018 (N = 2306)		2014 vs 2018 P-value
	%	(95% CI)	%	(95% CI)		%	(95% CI)	%	(95% CI)	
Do you believe that e-cigarettes are more or less harmful than regular cigarettes?										
Less harmful	31.9	(29.0, 35.1)	20.2	(16.3, 24.8)	< 0.001	30.6	(28.7, 32.7)	31.5	(29.0, 34.2)	0.720
Equally harmful	15.9	(13.6, 18.4)	18.3	(14.4, 22.9)	0.377	16.9	(15.3, 18.6)	22.5	(19.3, 26.5)	0.016
More harmful	4.3	(3.1, 5.8)	4.5	(3.4, 5.9)	0.878	3.2	(2.4, 4.1)	5.1	(3.9, 6.5)	0.042
I have never heard of e-cigarettes/I don't know enough	47.9	(44.7, 51.1)	57.0	(51.8, 62.1)	0.004	49.3	(47.1, 51.5)	40.9	(38.1, 43.7)	0.011
Do you believe that e-cigarettes are more or less addictive than cigarettes?										
Less addictive	15.0	(13.0, 17.3)	12.3	(9.5, 15.7)	0.181	18.8	(17.1, 20.6)	18.8	(29.5, 39.1)	0.997
Equally addictive	26.0	(23.2, 29.0)	18.5	(14.5, 23.4)	0.027	25.9	(24.0, 27.8)	12.0	(9.0, 15.7)	0.682
More addictive	7.8	(6.1, 10.0)	4.8	(3.7, 6.3)	0.052	3.7	(2.9, 4.6)	29.6*	(14.5, 51.1)	< 0.001

(Continued)

Table 2. Continued.

NEW YORK CITY (NYC)										
AMONG THOSE WHO NEVER TRIED E-CIGARETTES										
	MIDDLE SCHOOL (GRADES 6 THROUGH 8)					HIGH SCHOOL (GRADES 9 THROUGH 12)				
	2014 (N = 1173)		2018 (N = 1230)		2014 VS 2018 P- VALUE	2014 (N = 1894)		2018 (N = 1289)		2014 VS 2018 P- VALUE
	%	(95% CI)	%	(95% CI)		%	(95% CI)	%	(95% CI)	
I have never heard of e-cigarettes/I don't know enough	51.1	(47.9, 54.3)	64.4	(59.2, 69.3)	< 0.001	51.7	(49.5, 53.9)	46.7		0.173
Do you think using e-cigarettes make young people look cool?										
Yes	8.8	(7.1, 10.9)	11.6	(9.1, 14.8)	0.150	10.3	(9.1, 11.7)	21.2	(18.9, 23.7)	< 0.001
When you go to a convenience store, supermarket, gas station, or pharmacy/drug store, how often do you see ads for e-cigs or items that have e-cigs' company names or pictures on them?										
All/Most of the time	32.4	(29.3, 35.5)	31.3	(26.6, 36.4)	0.706	34.7	(32.6, 36.9)	42.4	(39.7, 45.2)	< 0.001
Some of the time	24.5	(21.8, 27.4)	32.4	(27.6, 37.6)	0.001	23.8	(22.0, 25.8)	24.3	(22.0, 26.8)	0.808
Hardly ever/Never	38.0	(35.0, 41.2)	33.4	(28.6, 38.5)	0.202	34.0	(31.9, 36.2)	29.0	(26.4, 31.7)	0.049
I never go to a convenience store, supermarket, or gas station	5.1	(4.0, 6.6)	2.9	(2.0, 4.3)	0.159	7.8	(6.7, 9.1)	4.3	(3.3, 5.6)	0.005
When you watch TV or go to the movies, how often do you see ads promoting electronic cigarettes or e-cigs?										
All/Most of the time	12.3	(10.2, 14.7)	13.6	(10.4, 17.6)	0.549	11.1	(9.8, 12.6)	16.1	(14.1, 18.3)	0.003
Some of the time	22.6	(20.0, 25.4)	22.9	(18.6, 27.9)	0.862	27.1	(25.2, 29.2)	23.5	(21.2, 26.0)	0.042
Hardly ever/Never	61.4	(58.2, 64.5)	57.7	(52.5, 62.8)	0.183	54.8	(52.6, 57.0)	51.8	(48.9, 54.6)	0.168
I do not watch TV or go to the movies	3.6	(2.8, 4.6)	5.8	(4.5, 7.4)	0.248	6.9	(5.9, 8.1)	8.7	(7.3, 10.3)	0.204

Bold means statically significant ($P < 0.05$).

Confidence intervals (CIs) are a measure of estimate precision: the wider the CI, the more imprecise the estimate.

relative harmfulness, and perceived relative addictiveness. Furthermore, we conducted a logistic regression model (2014, 2016, and 2018) with an interaction term to assess whether trends in e-cigarette use differed (ie, diverged or converged) over time between NYC and ROS. All differences emphasized in the text are statistically significant ($P < .05$) unless otherwise indicated. All comparisons are 2014 vs 2018 unless otherwise stated.

Results

Trends in current e-cigarette use among NYC and ROS middle and high school students are shown in Figure 1. Among middle

school students, the patterns of current use differed over time between NYC and ROS. Use was higher in NYC than in ROS in 2014 (4.6% vs 2.2%) and 2016 (9.0% vs 4.8%) but declined in NYC from 2016 to 2018, while it continued to increase in ROS. As of 2018, use had converged between the two regions: NYC use was similar to that of 2014 and there was no difference in use between NYC and ROS. In contrast, among high school students, use rose from 2014 to 2018 in both NYC (8.1% to 23.5%) and ROS (12.0% to 29.3%). Use remained higher in ROS than NYC over the period with parallel trends. These patterns persisted in the multivariable model (data not shown).

Table 3. Multivariate models of middle and high school students in NYC by e-cigarette users and knowledge and beliefs, 2014-2018.

NEW YORK CITY									
CURRENT E-CIGARETTE USE			BELIEVES E-CIGS ARE LESS HARMFUL			BELIEVES E-CIGS ARE LESS ADDICTIVE			LIKELY TO TRY AN E-CIGARETTE ANYTIME IN THE NEXT YEAR
	MIDDLE SCHOOL (GRADES 6 THROUGH 8)	HIGH SCHOOL (GRADES 9 THROUGH 12)	MIDDLE SCHOOL (GRADES 6 THROUGH 8)	HIGH SCHOOL (GRADES 9 THROUGH 12)	MIDDLE SCHOOL (GRADES 6 THROUGH 8)	HIGH SCHOOL (GRADES 9 THROUGH 12)	MIDDLE SCHOOL (GRADES 6 THROUGH 8)	HIGH SCHOOL (GRADES 9 THROUGH 12)	
	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Year									
2014	REF	REF	REF	REF	REF	REF	REF	REF	REF
2018	1.60 (0.83-3.11)	6.15 (4.04-9.36)	0.54 (0.40-0.73)	0.83(0.68-1.00)	0.80 (0.55-1.15)	0.87 (0.61-1.23)	1.62 (0.78-3.36)	2.19 (1.52-3.17)	
Gender									
Female	REF	REF	REF	REF	REF	REF	REF	REF	REF
Male	0.67 (0.36-1.27)	1.20 (0.91-1.59)	0.96 (0.67-1.40)	1.21 (1.00-1.46)	0.93 (0.68-1.27)	1.09 (0.87-1.37)	0.98 (0.42-2.28)	0.49 (0.35-0.69)	
Race/Ethnicity									
Latino	REF	REF	REF	REF	REF	REF	REF	REF	REF
White, non-Latino	0.81 (0.29-2.23)	0.85 (0.65-1.12)	1.42 (0.83-2.45)	1.57 (1.22-2.03)	1.55 (1.06-2.29)	1.19 (0.87-1.62)	1.17 (0.47-2.92)	0.78 (0.49-1.23)	
Black, non-Latino	0.76 (0.40-1.41)	0.42 (0.27-0.64)	1.04 (0.72-1.50)	0.95 (0.77-1.18)	1.35 (0.90-2.03)	1.04 (0.80-1.34)	1.87 (0.77-4.52)	0.65 (0.38-1.10)	
Asian, non-Latino	0.57 (0.20-1.63)	0.37 (0.23-0.61)	0.65 (0.46-0.90)	0.98 (0.73-1.33)	0.93 (0.52-1.64)	0.89 (0.65-1.23)	0.41 (0.10-1.79)	0.77 (0.46-1.31)	
Other, non-Latino	1.67 (0.64-4.35)	0.89 (0.46-1.74)	0.40 (0.16-1.00)	0.86 (0.58-1.27)	0.64 (0.27-1.52)	1.21 (0.73-2.00)	0.84 (0.09-7.92)	0.74 (0.16-3.55)	
How many of your friends smoke cigarettes									
None	REF	REF	REF	REF	REF	REF	REF	REF	REF
1 or more	6.45 (3.20-12.99)	3.12 (2.31-4.22)	1.46 (0.96-2.23)	1.42 (1.14-1.75)	1.60 (0.96-2.65)	1.61 (1.23-2.10)	4.01 (1.21-13.28)	1.80 (1.03-3.14)	
Not sure	2.29 (1.25-4.20)	1.21 (0.75-1.95)	1.46 (0.82-2.62)	0.91 (0.64-1.28)	1.24 (0.70-2.23)	0.83 (0.53-1.31)	1.61 (0.53-4.87)	2.15 (1.09-4.25)	
Current Cigarette Smoker									
No	REF	REF	REF	REF	REF	REF	REF	REF	REF
Yes	25.53 (7.81-83.46)	8.02 (4.50-14.31)	0.81 (0.20-3.33)	0.59 (0.36-0.96)	1.11 (0.29-4.33)	0.64 (0.42-1.00)	2.61 (0.33-20.58)	10.00 (3.08-32.43)	
Current e-cigarette user									
No	REF	REF	REF	REF	REF	REF	REF	REF	REF
Yes	7.20 (4.37-11.85)	3.54 (3.01-4.17)	5.94 (2.69-13.13)	3.78 (2.91-4.89)					
Believes e-cigarettes are less harmful than traditional cigarettes									

(Continued)

Table 3. Continued.

NEW YORK CITY		CURRENT E-CIGARETTE USE		BELIEVES E-CIGS ARE LESS HARMFUL		BELIEVES E-CIGS ARE LESS ADDICTIVE		LIKELY TO TRY AN E-CIGARETTE ANYTIME IN THE NEXT YEAR	
		MIDDLE SCHOOL (GRADES 6 THROUGH 8)	HIGH SCHOOL (GRADES 9 THROUGH 12)	MIDDLE SCHOOL (GRADES 6 THROUGH 8)	HIGH SCHOOL (GRADES 9 THROUGH 12)	MIDDLE SCHOOL (GRADES 6 THROUGH 8)	HIGH SCHOOL (GRADES 9 THROUGH 12)	MIDDLE SCHOOL (GRADES 6 THROUGH 8)	HIGH SCHOOL (GRADES 9 THROUGH 12)
		AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Equal/More/I don't know						REF	REF	REF	REF
Less						6.41 (2.62-15.67)	3.04 (1.84-5.02)		
Believes e-cigarettes are less harmful than traditional cigarettes									
Equal/More/I don't know						REF	REF	REF	REF
Less						1.46 (0.43-4.90)	3.48 (2.10-5.77)		

Bold means statically significant ($P < 0.05$).

Confidence intervals (CIs) are a measure of estimate precision: the wider the CI, the more imprecise the estimate.

*Among those who have never tried an e-cigarette before.

†Is this significant even though 1.00 is in the 95% CI.

Current e-cigarette use rose among both female (6.2% vs 23.9%) and male (10.4% vs 22.7%) high school students (Table 1). Current e-cigarette use among White (6.7% vs 27.9%), Black (5.2% vs 12.6%), Latino (10.7% vs 34.1%), and Asian (5.0% vs 12.0%) high school students all increased. Prevalence of current e-cigarette use among high school (3.0% vs 17.8%) students with no friends who smoke cigarettes increased. Current e-cigarette use among high school students who use cigarettes (44.7% vs 77.4%) increased. Among high school students with one or more friends who smoke cigarettes, prevalence of current e-cigarette use increased from one in five to almost one in two (17.9% vs 48.7%). The prevalence of ever e-cigarette use doubled among high school (19.4% vs 45.4%) students (Table 1). Patterns differed among middle school students, with an overall increase between 2014 and 2016 (4.8% vs 9.0%), but no increase between 2014 and 2018 (5.7%).

In ROS, there was an upsurge in current e-cigarette use among both middle school (2.2% vs 7.4%) and high school (12.0% vs 29.3%) students (Figure 1). The prevalence of ever e-cigarette use increased among middle school (4.9% vs 13.2%) and high school (23.0% vs 44.6%) students as well (Figure 1).

Table 2 shows results from bivariate analyses examining changes in NYC middle and high school students' knowledge and attitudes about e-cigarettes. Among middle school students, the prevalence of believing e-cigarettes are less harmful than regular cigarettes decreased (31.9% vs 20.2%), and high school students increasingly believed e-cigarettes are equally harmful (16.9% vs 22.5%) and/or more harmful than regular cigarettes (3.2% vs 5.1%). High school students were less likely to say e-cigarettes and cigarettes are equally addictive and or less addictive; they were more likely to say they were more addictive. The prevalence of youth saying they do not know enough to assess e-cigarette addictiveness increased among middle school students between 2014 (51.1%) and 2018 (64.4%) and was unchanged among high school students (51.7% in 2014; 46.7% in 2018; P -value = .173). The perception that using e-cigarettes makes young people look cool increased among both middle (8.8% vs 11.6%) and high school (10.3% vs 21.2%) students between 2014 and 2018 in NYC (Table 2).

Table 2 also shows reported exposure to e-cigarette advertising. Exposure to e-cigarette advertising in stores (all/most of the time) increased among high school (34.7% vs 42.4%) students between 2014 and 2018. Television and film advertising exposure also increased between 2014 (11.1%) and 2016 (16.1%) among high school students (Table 2).

Table 3 presents adjusted odd ratios (AOR) for the four outcome variables of interest among NYC middle and high school students. High school (AOR = 6.15; 95% CI = 4.04-9.36) students in 2018 were six times more likely to be a current e-cigarette user than students in 2014. NYC middle school students had 46% (AOR = .54; 95% CI = .40-.73) lower odds of believing that e-cigarettes are less harmful than cigarettes in 2018 compared with 2014. The odds of willingness to try e-cigarettes anytime in the next year were twice as high (AOR =

2.19; 95% CI = 1.15-3.17) in 2018 compared with 2014 among NYC high school students.

Discussion

There has been an upsurge of e-cigarette availability, brands, and flavors in the past few years and e-cigarette use among youth has garnered increased attention. Due to the rapidly changing e-cigarette environment, we conducted the first study that uses population-level data to measure e-cigarette use among middle and high school students in NYC. We also sought to assess e-cigarette use in light of NYC's early adoption of T21, inclusive of e-cigarettes, in 2014.

We found that the odds of current e-cigarette use were six times higher among high school students in NYC in 2018 than in 2014. Our data show significant increases in current e-cigarette use among high school students regardless of gender and race. The National Youth Tobacco Survey (NYTS) data reported a general decline between 2015 and 2017 among middle and high school students currently using e-cigarettes.³¹ Unfortunately, between 2017 and 2018, the data showed middle and high school students currently using e-cigarettes has sharply increased to levels exceeding 2015.³¹ However, between 2014 and 2018, our NYC data indicates current e-cigarette use among middle school students did not increase significantly.

The minimum age of purchase remained 18 years of age in most of ROS during the study period. There were significant, comparable increases in current e-cigarette use among high school students in NYC (8.1%-19.0%) and ROS (12.0%-21.5%) after T21 was implemented in NYC, suggesting that T21 had a limited impact on e-cigarette use among NYC high school students between 2014 and 2016 (Figure 1). These findings are similar to a study comparing NYC youth with other local jurisdictions soon after T21.³² T21 may have had a stronger impact on middle school students given their greater distance from legal purchasing age. In contrast, high school students might have had more access to social networks with those 21 and older, or the means to travel to and purchase from areas near NYS where T21 was not in effect.³³

During our study period, NYC had no requirements for retailers to obtain a license to sell e-cigarette products, which meant that although T21 was in place, a list of NYC e-cigarette retailers was not available to enable systematic inspections and enforcement in the initial years following adoption of the law. Also, differing age restrictions in adjacent areas, including elsewhere in New York State, suggest youth, particularly of high school ages, may have had relatively easy ability to purchase.³⁴ In 2018, a new NYC law went into effect, requiring e-cigarette retailers to obtain a license, which has since facilitated monitoring and enforcement of the age restriction.³⁵

As observed nationally, we found that in NYC, e-cigarette use is more prevalent than cigarette smoking among youth.³⁶ Additionally in NYC, current e-cigarette use increased between 2014 and 2018, while current cigarette smoking stagnated

among high school students. Social norms regarding e-cigarette use compared with cigarette use are changing, with e-cigarettes becoming the more favored choice.²⁶ This is likely multifactorial. The most commonly selected reason for using e-cigarettes among US middle and high school students is related to peer and family use, “friend or family member used them (39%),” followed by availability of flavors (31%) and perceived lower risk than other forms of tobacco such as cigarettes (17%).¹⁰ There are also bi-directional associations between e-cigarette use and cigarette smoking: youth who use e-cigarettes are more likely to try cigarettes and vice versa, which aligns with what we observed.¹⁷ The odds of current e-cigarette use were much higher among high school students with one or more friends who smoke cigarettes than among high school students without friends who smoke cigarettes.

The relationship between prevalence changes and shifting perceptions of product risks appears to be complex and evolving in this population. The National Youth Tobacco Survey (NYTS) 2012–2014 showed most United States (US) youth view e-cigarettes as less harmful and addictive than cigarettes.³⁷ NYC middle and high school students had 46% and 17% lower odds, respectively, in 2018 compared with 2014 of believing e-cigarettes were less harmful than cigarettes, suggesting that a greater sense of harm is not sufficient to curtail e-cigarette use. The NYTS also found that only 26.2% of youth felt unable to provide an opinion on the safety of e-cigarettes.³⁷ Our results show that close to half of high school students and more than 60% of middle school students felt they did not have enough information to answer the questions on believing that e-cigarettes are more or less addictive than cigarettes, despite the increase in use, which highlights the importance of more education.

Youth exposure to e-cigarette marketing and product use has become a substantial concern in recent years.^{38–40} Our study indicated that in 2018, middle and high school students’ exposure to e-cigarettes increased through visiting stores, watching TV, and going to the movies compared with 2014. Recent studies have suggested that youth who are exposed to e-cigarette marketing have an increased likelihood of also using e-cigarettes.^{24,40} A study done by Mantey in 2016 showed a significant association between exposure to e-cigarette marketing and vulnerability to use e-cigarettes among youth who had never used e-cigarettes.²⁴

E-cigarette susceptibility increased among high school students over time in NYC, but not among middle school students. Among those who had never used e-cigarettes in 2018, high school students were two times more likely to try an e-cigarette anytime in the next year, compared with students in 2014. US survey data reveal that youth are more aware of e-cigarettes and that use of e-cigarettes is rapidly increasing in this population.⁴¹ When surrounded by peers who smoke, perceptions of smoking can be normalized; this appears to be true for both e-cigarettes and cigarettes. The lack of increased susceptibility among NYC middle school students thus aligns

with our observed decreased use. As noted above, this difference between high school and middle school students may reflect variable impact of T21, based on distance from legal purchasing age.

Limitations

This study is not without limitations. First, because only students from public and private schools are recruited in the YTS, the findings may not be generalizable to youths who are home-schooled, in detention centers, or have dropped out of school. Second, YTS is cross-sectional and provides only population snapshots. While we examined variation by available demographics, YTS does not capture family income or school characteristics that might be important for understanding e-cigarette use. Lastly, self-reported data are subject to under-reporting, recall bias, and desirability bias. However, we expect these self-reporting issues to be similar in all waves of the YTS and not affected by T21 implementation.

Conclusion

E-cigarette use increased significantly among NYC high school students between 2014 and 2018, despite the adoption of T21. This increase is similar to trends seen nationally and among students in ROS, where T21 was not widely enacted. Our data indicate a decrease in e-cigarette use among NYC middle school students between 2014 and 2018 after T21 was implemented. Previous studies have shown that students often access vaping products such as e-cigarettes for the first time in school.^{42,43} Students have also reported that borrowing and selling products to other classmates were very common.⁴¹ Policies, programs, and educational campaigns which denormalize e-cigarette use and make e-cigarettes more difficult for high school students to access are needed to decrease high school e-cigarette use.

After our period of study, local and federal governments have taken additional actions to reduce access and use. On December 20th, 2019, the President signed T21, amending the Federal Food, Drug, and Cosmetic Act, and raising the federal minimum age for sale of tobacco products from 18 to 21 years.⁴⁴ Due to T21, it is now illegal for retailers to sell tobacco products to anyone under 21 nationwide.⁴⁴ Locally, NYC adopted an e-cigarette retail license in August 2018 and passed a ban on the sale of flavored e-cigarette products, effective from July 2020. Additional efforts to limit e-cigarette marketing are needed to reduce youth exposure to these products. Further research, including qualitative studies and focus groups, is needed to understand why youth are initiating e-cigarette use and what informs their perceptions surrounding relative harmfulness and addictiveness of e-cigarettes compared with cigarettes.

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