Rural-Urban Differences in Changes and Effects of Tobacco 21 in Youth E-cigarette Use

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abstract

BACKGROUND: The prevalence of current electronic cigarette (e-cigarette) use has increased dramatically among US youth. It is unknown how the impact of policies to curb e-cigarette use might differ across rural and urban areas.

METHODS: Data were collected from an annual statewide survey of middle and high school students in Kansas. Multivariable logistic regression was performed to examine the temporal change in current e-cigarette use in 2018 and 2019 across rural and urban areas and across the areas with and without a Tobacco 21 (T21) policy that raises the minimum age of tobacco sales to 21 years.

RESULTS: Of 132 803 participants, the prevalence of current e-cigarette use increased from 8.2% in 2018 to 12.6% in 2019. The increase was larger in rural areas (from 6.7% in 2018 to 13.4% in 2019, difference = 6.7%) than in urban areas (9.8%–11.9%, difference = 2.1%), with a significant interaction effect of year × urbanicity/T21 group ($P < .0001$). In urban areas, e-cigarette use increased significantly for middle school students in T21 areas (3.3%–4.5%; $P = .01$) and all students in non-T21 areas (8.1%–12.0%; $P < .0001$). In rural areas, the increase in e-cigarette use was significant in both T21 and non-T21 areas for all students, but the increase was smaller in T21 (7.9%–10.8%, difference = 3.0%) than in non-T21 areas (6.5%–13.7%, difference = 7.1%).

CONCLUSIONS: In this study, we reported marked disparities in the increase of youth e-cigarette use, with a larger recent increase in rural than in urban areas. T21 policies appear to mitigate these increases in both rural and urban youth.

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WHAT'S KNOWN ON THIS SUBJECT: Current electronic cigarette (e-cigarette) use increased dramatically among US youth from 2017 to 2019, and it has been reaching epidemic proportions.

WHAT THIS STUDY ADDS: In this study, we found marked disparities in the increase of youth e-cigarette use, with a much larger recent increase in rural than in urban areas. Tobacco 21 policies may curb increases in e-cigarette use among youth.

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Although the cigarette smoking prevalence among youth has been declining over the last several decades,[1,2] use of electronic cigarettes (e-cigarettes) among teenagers is gaining popularity. The prevalence of current e-cigarette use has increased dramatically from 11.7% to 27.5% for high school students and from 3.3% to 10.5% for middle school students between 2017 and 2019.[3,4] Understanding trends in youth e-cigarette use is important because use has been linked to increased risk of tobacco and marijuana use[5–7] and associated severe respiratory disease.[8]

In previous studies of adolescent nicotine and tobacco use trends, researchers have documented important rural–urban disparities,[9–11] with rural residents reporting a higher prevalence of cigarette smoking and use of cigars and smokeless tobacco products than urban residents. However, in studies that explored the use of e-cigarettes across urban and rural areas in the period between 2013 and 2014, researchers found no significant rural-versus-urban differences for both adults[12] and adolescents.[13] Studies of more recent e-cigarette use among US adolescents, especially whether there are differences in how e-cigarette use is changing across urban and rural areas, are lacking.

In addition to evidence of a rising trend of adolescent e-cigarette use, the policy landscape for the use of tobacco products has changed with the introduction of Tobacco 21 (T21) ordinances.[14] As of November 2019, 530 jurisdictions across 26 states had raised the minimum legal age of tobacco sales from 18 to 21 in an effort to reduce tobacco use prevalence, affecting more than half of the US population.[15] Although previous empirical studies have revealed the effectiveness of T21 in reducing cigarette smoking prevalence among adolescents[16] and young adults,[17,18] the impact of T21 on adolescent e-cigarette use remains unknown, and it is unclear whether the impact will be uniform across rural and urban areas. Between November 2015 and March 2019, 22 cities or localities in Kansas passed T21 laws, whereas 77% of the 2.9 million population in Kansas retained the minimum legal age of tobacco sales at 18 years old.[19] This sets up a natural experiment to evaluate the impacts of T21 on youth tobacco use.

To address these gaps in knowledge, researchers used data from the 2018 and 2019 Kansas Communities That Care (KCTC) Student Survey to test the following 2 research questions: (1) are there differences in adolescent e-cigarette use and patterns of change across rural and urban areas, and (2) does T21 moderate any changes in e-cigarette use among youth, with differential effects, in rural and urban areas?

METHODS

KCTC Survey

The KCTC Student Survey is a cross-sectional, school-based, annual survey that has been used to track teenagers' use of harmful substances, such as alcohol, tobacco, and other drugs, since 1994.[20] The KCTC surveys are offered to students in 6th, 8th, 10th, and 12th grades by using a census sample open to all public and private schools in Kansas at no charge to the districts. A majority of schools (78%) participated in KCTC in both years. The survey is conducted from November 1 to January 31 of each year. Monthly e-mail reminders were sent to schools that had not yet registered by survey closure on January 31. Overall, 220 school districts and 61 046 students participated in the KCTC survey in 2018, with a combined school and student response rate of 42.5%. In 2019, 232 school districts and 71 757 students participated in the survey, with a combined school and student response rate of 49.4%. The response rate was calculated by dividing the number of completed, validated surveys by the total number of eligible students. In 2018, 74% of all Kansas school districts participated. In 2019, 81% of all districts participated. Districts were required to obtain written parent consent for student participation. The percentage of parents that provided written consent varied among districts and years, which accounts for the differences between reported student and district participation rates across years. However, participation was well distributed across the state, with the percentages of sex, race, and population density similar to demographic data reported by the Kansas State Department of Education. Participation in the 2018 and 2019 KCTC survey was anonymous and voluntary. Details of the survey instrument can be found in a previous study.[21] Because researchers used only deidentified data in this study, it was deemed as exempt by the Children's Mercy Hospital Institutional Review Board.

Measures

E-Cigarette and Other Tobacco Use Status

E-cigarette use was assessed by asking, "during the past 30 days, on how many days have you used electronic cigarettes (e-cigarettes)?" Students who reported >0 days were defined as current e-cigarette users.[22] Similar questions were asked for other tobacco product use, including cigarettes, cigars (cigars, little cigars, and cigarillos), and smokeless tobacco. Those who reported >0 days of smoking cigarettes were defined as current cigarette smokers, and those who reported >0 days of cigar or smokeless tobacco use were defined as current other tobacco users.

T21 Policies and Urbanicity

We appended the T21 indicator (yes versus no) at each school separately for 2018 and 2019 by cross-referencing each school's location and data on localities with T21 laws available from Tobacco21.org.[19]

Rural–urban commuting area (RUCA) codes from the US Department of Agriculture[23] were used to classify the zip code of each school building as metropolitan, micropolitan, small town, or rural. The RUCA system derives the classification on the basis of the commuting pattern with the 2010 decennial census and the 2006 to 2010 American Community Survey data. A binary indicator was created to classify each zip code as urban (metropolitan) versus rural (micropolitan, small town, and rural).[24] On the basis of the T21 policy indicator and urbanicity, we further created a 4-level variable (urban-T21, urban–non-T21, rural-T21, and rural–non-T21) to categorize each school.

Covariates

Demographic covariates included sex (boy or girl), race and/or ethnicity (white, Black, Hispanic, or other), and grade (6th, 8th, 10th, and 12th). We also included language used most often at home (English, Spanish, or another language) and parental education level (highest level of education of either parent, categorized as high school or less, some college, college or above, and do not know or does not apply) to account for the socioeconomic status.[25]

Statistical Methods

The prevalence and 95% confidence interval (CI) of current e-cigarette use in 2018 and 2019 were reported by using the Taylor series variance estimation, overall and by demographic factors, urbanicity, T21 status, and other current tobacco use status. Multivariable logistic regression was used to test for changes in self-reported current e-cigarette use (the outcome variable) between 2018 and 2019 across risk factors, in which year was the predictive variable. We also examined the interaction terms between year × urbanicity/T21 group to decide whether separate models should be performed to examine changes in e-cigarette use separately for rural versus urban areas and T21 versus non-T21 areas, overall and stratified by middle (6th- or 8th-graders) and high (10th- or 12th-graders) school. Because not all schools (78.1%) participated in KCTC in both 2018 and 2019, we conducted a sensitivity analysis to examine the change in e-cigarette use among schools that participated in surveys in both years.

The strata by school districts and clustering of students within the school building were accounted for by using SAS (SAS Institute, Inc, Cary, NC) survey procedures.[26] Adjusted odds ratios (aORs) and 95% CIs were calculated in the multivariable logistic regression analysis. $P < .05$ (2-sided) was used as the threshold for statistical significance.

RESULTS

Of 132 803 students included in the study, 50.5% were girls; the 6th-, 8th-, 10th-, and 12th-grade student distribution was 29.1%, 28.6%, 24.0%, and 18.3%, respectively; 71.3% of students were white, 6.1% were Black, 6.7% were Hispanic, and 16.0% were other; 50.7% of students lived in urban areas, and 28.2% lived in areas with T21 ordinances (Table 1). As compared with students who lived in urban areas, students who lived in rural areas were more likely to be in 10th or 12th grade and be non-Hispanic white but less likely to live in T21 areas. For instance, 76.6% of respondents in rural areas were non-Hispanic white in comparison with 66.2% in urban areas; 9.2% of respondents in rural areas lived in T21 areas, as compared with 46.6% in urban areas. In Supplemental Table 4, we present the sample characteristics in 2018 and 2019. There were no differences in sex and grade distributions. The current use of cigarette smoking dropped from 3.4% in 2018 to 3.0% in 2019, and other tobacco use dropped from 5.3% in 2018 to 5.0% in 2019.

In Table 2, we present changes in current e-cigarette use from 2018 to 2019. Overall, the prevalence of current e-cigarette use increased from 8.2% in 2018 to 12.6% in 2019 (difference = 4.4% [95% CI: 4.1% to 4.8%]). The largest increase was observed among current other tobacco users (difference = 15.6% [94% CI 13.2% to 17.9%]), current cigarette smokers (difference = 13.4% [95% CI: 10.4% to 16.3%]), 12th-graders (difference = 8.4% [95% CI: 7.3% to 9.4%]), students with parental education of some college (difference = 6.9% [95% CI: 5.8% to 8.0%]), and students from rural areas (difference = 6.7% [95% CI: 6.3% to 7.2%]), whereas the smallest increase was observed among students with a language other than English or Spanish most used at home (difference = 0.3% [95% CI: −1.6% to 2.2%]), students from T21 areas (difference = 0.5% [95% CI: −0.2% to 1.2%]), sixth-graders (difference = 1.0% [95% CI: 0.8% to 1.3%]), and Black students (difference = 1.5% [95% CI: 0.3% to 2.6%]). In the multivariable analysis, the increase in current e-cigarette use was significant across almost all sociodemographics and other risk factors.

Sensitivity analysis of schools participating in both the 2018 and 2019 KCTC surveys included 537 schools (78.1% of all schools) and 118 769 students (89.4% of all participants). The increases in current e-cigarette use were consistent with the primary analysis, overall (8.0% in 2018 to 12.4% in 2019, difference = 4.4% [95% CI: 4.0% to 4.7%]) and by

TABLE 1 Sample Characteristics of the 2018–2019 KCTC Student Surveys, Overall and by Urbanicity (n = 132 803)

	N	Percentage (95% CI)	Urbanicity[a]				*P*[b]
			Urban		Rural		
			n	Percentage (95% CI)	*n*	Percentage (95% CI)	
Overall	132 803	100%	66 851	50.7 (50.4 to 51.0)	65 036	49.3 (49.0 to 49.6)	
Year							<.0001
2018	61 046	46.0 (45.7 to 46.2)	29 216	43.7 (43.3 to 44.1)	31 371	48.2 (47.9 to 48.6)	
2019	71 757	54.0 (53.8 to 54.3)	37 635	56.3 (55.9 to 56.7)	33 665	51.8 (51.4 to 52.1)	
Sex							.07
Girl	66 840	50.5 (50.2 to 50.8)	33 836	50.8 (50.4 to 51.2)	32 630	50.3 (49.9 to 50.7)	
Boy	65 517	49.5 (49.2 to 49.8)	32 798	49.2 (48.8 to 49.6)	32 268	49.7 (49.3 to 50.1)	
Grade							<.0001
Sixth	38 587	29.1 (28.9 to 29.4)	20 380	30.6 (30.2 to 30.9)	17 949	27.6 (27.3 to 28.0)	
Eighth	37 877	28.6 (28.3 to 28.8)	20 024	30.0 (29.7 to 30.4)	17 624	27.1 (26.8 to 27.5)	
10th	31 791	24.0 (23.8 to 24.2)	15 089	22.6 (22.3 to 22.9)	16 413	25.3 (24.9 to 25.6)	
12th	24 247	18.3 (18.1 to 18.5)	11 200	16.8 (16.5 to 17.1)	12 944	19.9 (19.6 to 20.2	
Race and/or ethnicity							<.0001
White	94 415	71.3 (71.0 to 71.5)	44 167	66.2 (65.8 to 66.6)	49 718	76.6 (76.2 to 76.9)	
Black	8047	6.1 (5.9 to 6.2)	5601	8.4 (8.2 to 8.6)	2369	3.6 (3.5 to 3.8)	
Hispanic	8879	6.7 (6.6 to 6.8)	5113	7.7 (7.5 to 7.9)	3691	5.7 (5.5 to 5.9)	
Other[c]	21 156	16.0 (15.8 to 16.2)	11 843	17.7 (17.5 to 18.0)	9160	14.1 (13.8 to 14.4)	
T21							<.0001
Non-T21 areas	95 288	71.8 (71.6 to 72.1)	35 616	53.4 (53.0 to 53.7)	59 033	90.8 (90.6 to 91.0)	
T21 areas	37 376	28.2 (27.9 to 28.4)	31 117	46.6 (46.3 to 47.0)	5999	9.2 (9.0 to 9.4)	
Current cigarette smoking							<.0001
No	119 933	96.8 (96.7 to 96.9)	59 861	97.5 (97.4 to 97.7)	59 272	96.1 (95.9 to 96.2)	
Yes	3970	3.2 (3.1 to 3.3)	1512	2.5 (2.3 to 2.6)	2433	3.9 (3.8 to 4.1)	
Current other tobacco use[d]							<.0001
No	116 402	94.8 (94.7 to 95.0)	58 325	96.0 (95.8 to 96.2)	57 302	93.7 (93.5 to 93.8)	
Yes	6350	5.2 (5.0 to 5.3)	2427	4.0 (3.8 to 4.2)	3884	6.3 (6.2 to 6.5)	
Parental education							
High school or lower	23 430	17.8 (17.6 to 18.0)	10 893	16.4 (16.2 to 16.7)	12 361	19.2 (18.9 to 19.5)	<.0001
Some college	15 741	12.0 (11.8 to 12.1)	7411	11.2 (10.9 to 11.4)	8222	12.7 (12.5 to 13.0)	
College	71 042	54.0 (53.7 to 54.2)	37 251	56.2 (55.9 to 56.6)	33 365	51.7 (51.3 to 52.1)	
Do not know or does not apply	21 425	16.3 (16.1 to 16.5)	10 686	16.1 (15.9 to 16.4)	10 550	16.4 (16.1 to 16.6)	
Language used most at home							<.0001
English	115 304	89.7 (89.6 to 89.9)	57 001	88.2 (87.9 to 88.4)	57 566	91.4 (91.2 to 91.6)	
Spanish	10 406	8.1 (7.9 to 8.2)	5653	8.7 (8.5 to 9.0)	4657	7.4 (7.2 to 7.6)	
Another language	2778	2.2 (2.1 to 2.2)	1982	3.1 (2.9 to 3.2)	778	1.2 (1.1 to 1.3)	

[a] A binary indicator was created to classify each zip code as urban (metropolitan) versus rural (micropolitan, small town, and rural) on the basis of the RUCA system.
[b] Rao-Scott χ^2 test was conducted to detect significant group differences.
[c] Includes students who are Asian American, American Indian and/or Alaskan Native, Native Hawaiian and/or other Pacific Islander, and multiple races.
[d] Past 30-d use of cigars (ie, cigars, cigarillos, and little cigars) and smokeless tobacco products.

sociodemographic groups and tobacco use status (see Supplemental Table 5).

In Table 3, we present the stratified analysis of changes in current e-cigarette use across urbanicity and T21 status. The interaction term between year × urbanicity/T21 group was significant ($P < .0001$). In urban areas, current e-cigarette use increased significantly from 8.1% in 2018 to 12.0% in 2019 (difference = 3.9% [95% CI: 3.3% to 4.6%], aOR = 1.8 [1.6–2.0]; $P < .0001$) in non-T21 areas but not in T21 areas (difference = −0.1% [95% CI: −0.8% to 0.7%], aOR = 1.1 [0.9–1.3]; $P = .36$). In rural areas, the increase in current e-cigarette use was significant in both T21 (difference = 3.0% [95% CI: 1.5% to 4.5%]) and non-T21 areas (difference = 7.1% [95% CI: 6.6% to 7.6%]), but the increase was larger in non-T21 areas (aOR = 3.1 [2.8–3.4]) than in T21 areas (aOR = 1.8 [1.2–2.6]). The stratified analysis by middle and high school reveals similar results except that the change was significant for the middle school students (aOR = 1.4 [1.1–1.9]; $P = .01$) but not for high school students ($P = .96$) in urban T21 areas.

In Supplemental Table 6, we present changes in e-cigarette use from 2018 to 2019 by grade and urbanicity/T21 group. In non-T21 regions, the change in e-cigarette use was significant across all grades (6th, 8th, 10th, and 12th) in both urban and rural areas. In T21 regions, the change was only significant in the 8th grade in urban areas, whereas the change was significant in all grades in rural areas except the 12th grade.

DISCUSSION

In 2019, >5.2 million US adolescents reported current use of e-cigarettes,

TABLE 2 Changes in Current E-cigarette Use Among Youth From 2018 to 2019, 2018–2019 KCTC Student Surveys (n = 132 803)

Factors (n = 132 803)	Prevalence of Current E-Cigarette Use			
	Percentage (95% CI)		Change Across Years	
	2018	2019	Change	P[a]
Overall	8.2 (8.0 to 8.4)	12.6 (12.3 to 12.8)	4.4 (4.1 to 4.8)	<.0001
Sex				
Girl	7.3 (7.0 to 7.6)	12.2 (11.8 to 12.5)	4.9 (4.4 to 5.3)	<.0001
Boy	9.0 (8.7 to 9.4)	13.0 (12.7 to 13.4)	4.0 (3.5 to 4.5)	<.0001
Grade				
Sixth	1.1 (0.9 to 1.2)	2.1 (1.9 to 2.3)	1.0 (0.8 to 1.3)	<.0001
Eighth	5.1 (4.8 to 5.5)	8.9 (8.5 to 9.3)	3.7 (3.2 to 4.2)	<.0001
10th	12.4 (11.8 to 12.9)	18.8 (18.2 to 19.4)	6.4 (5.6 to 7.3)	<.0001
12th	17.5 (16.8 to 18.2)	25.9 (25.1 to 26.6)	8.4 (7.3 to 9.4)	<.0001
Race and/or ethnicity				
White	8.9 (8.6 to 9.2)	13.9 (13.6 to 14.2)	5.1 (4.6 to 5.5)	<.0001
Black	5.5 (4.7 to 6.4)	7.0 (6.2 to 7.8)	1.5 (0.3 to 2.6)	.02
Hispanic	4.3 (3.7 to 5.0)	8.9 (8.0 to 9.7)	4.5 (3.5 to 5.6)	<.0001
Other[b]	7.3 (6.7 to 7.8)	10.2 (9.7 to 10.8)	3.0 (2.2 to 3.8)	<.0001
Urbanicity[c]				
Urban	9.8 (9.5 to 10.2)	11.9 (11.5 to 12.2)	2.1 (1.6 to 2.6)	<.0001
Rural	6.7 (6.4 to 7.0)	13.4 (13.0 to 13.8)	6.7 (6.3 to 7.2)	<.0001
T21				
Non-T21 area	7.1 (6.8 to 7.3)	13.0 (12.7 to 13.3)	5.9 (5.5 to 6.3)	<.0001
T21 area	11.1 (10.6 to 11.6)	11.6 (11.2 to 12.1)	0.5 (−0.2 to 1.2)	0.08
Current other tobacco use[d]				
No	5.6 (5.4 to 5.8)	9.6 (9.4 to 9.8)	4.0 (3.7 to 4.3)	<.0001
Yes	55 (53.2 to 56.8)	70.5 (69 to 72.1)	15.6 (13.2 to 17.9)	<.0001
Parental education				
High school or lower	7.9 (7.3 to 8.4)	14.1 (13.5 to 14.7)	6.3 (5.4 to 7.1)	<.0001
Some college	9.6 (8.9 to 10.3)	16.5 (15.7 to 17.3)	6.9 (5.8 to 8.0)	<.0001
College	9.3 (9.0 to 9.7)	13.4 (13 to 13.7)	4.1 (3.6 to 4.5)	<.0001
Do nott know or does not apply	3.3 (2.9 to 3.6)	5.3 (4.9 to 5.7)	2.0 (1.4 to 2.6)	<.0001
Language most used at home				
English	8.5 (8.3 to 8.8)	13.1 (12.8 to 13.4)	4.6 (4.2 to 4.9)	<.0001
Spanish	4.5 (3.8 to 5.1)	8.7 (7.9 to 9.4)	4.2 (3.2 to 5.2)	<.0001
Another language	6.1 (4.7 to 7.4)	6.4 (5.1 to 7.7)	0.3 (−1.6 to 2.2)	.46

[a] Multivariable logistic regressions were performed to examine the changes in e-cigarette use (dependent variable), in which the survey year 2018 serves as the reference. The models were adjusted by sex, grade, race and/or ethnicity, T21 area, urbanicity, current cigarette smoking, current other tobacco use, parental education, and language used most often at home.
[b] Includes students who are Asian American, American Indian and/or Alaskan Native, Native Hawaiian and/or other Pacific Islander, and multiple races.
[c] A binary indicator was created to classify each zip code as urban (metropolitan) versus rural (micropolitan, small town, and rural) on the basis of the RUCA system.
[d] Past 30-d use of cigars (ie, cigars, cigarillos, and little cigars) and smokeless tobacco products.

with >1 in 4 students in the 12th grade and >1 in 5 in the 10th grade reporting use of e-cigarettes in the past 30 days.[3,27] This study is one of the first in which researchers identify a significant disparity in changes of youth e-cigarette use across urban and rural areas. Whereas previous national data from 2013 to 2014 found no difference in adolescent e-cigarette use between urban and rural areas, our data revealed a striking pattern in which the prevalence of rural youth e-cigarette use overtook the prevalence in urban youth, with the prevalence of e-cigarette use in rural areas (13.4%) surpassing that in urban areas (11.9%) in 2019. The increase in current e-cigarette use among Kansas middle and high school students from 2018 to 2019 was >3 times higher in rural areas (6.7%) than in urban areas (2.1%). In contrast, the overall current use of cigarette smoking and other tobacco use dropped from 2018 to 2019 for Kansas students.

These statistics are concerning because e-cigarettes contain varying levels of nicotine and a number of potentially toxic substances (eg, carbonyl compounds, tobacco-specific nitrosamines, heavy metals, glycols, and volatile organic compounds).[11] E-cigarette use during adolescence may serve as a gateway for future cigarette and other substance use.[5–7] The rapid increase in youth e-cigarette use in rural areas may be due to several reasons. First, rural areas are less likely than urban areas to be protected by comprehensive tobacco control policies (eg, smoke-free laws),[28] which are effective in reducing youth tobacco use.[29] Second, youth in rural areas are less likely to be exposed to antitobacco messages in the media.[30] For instance, youth in rural areas may be less likely to be exposed to the current US Food and Drug Administration "The Real Cost" campaign, which focuses on

TABLE 3 Changes in Current E-Cigarette Use Among Youth From 2018 to 2019 in Urban and Rural Communities With or Without T21 Ordinances (N = 132 803), Overall and Stratified by Middle and High School

Full Analysis, N = 132 803					
	Prevalence of Current E-Cigarette Use, % (95% CI)			aOR (95% CI)[a]	P[a]
Urbanicity-T21 Groups	2018	2019	Change		
Urban non-T21 region	8.1 (7.6 to 8.5)	12.0 (11.5 to 12.5)	3.9 (3.3 to 4.6)	1.8 (1.6 to 2.0)	<.0001
Urban T21 region	11.8 (11.3 to 12.4)	11.7 (11.3 to 12.2)	−0.1 (−0.8 to 0.7)	1.1 (0.9 to 1.3)	.36
Rural non-T21 region	6.5 (6.3 to 6.8)	13.7 (13.3 to 14.1)	7.1 (6.6 to 7.6)	3.1 (2.8 to 3.4)	<.0001
Rural T21 region	7.9 (6.9 to 8.8)	10.8 (9.7 to 12.0)	3.0 (1.5 to 4.5)	1.8 (1.2 to 2.6)	.002
Interaction of Year X Urbanicity-T21 Group	—	—	—	—	<.0001
Stratified Analysis	—	—	—	—	—
Graders = 6 or 8 (n = 76 464)	—	—	—	—	—
Urban non-T21 region	4.0 (3.6 to 4.4)	6.4 (5.9 to 6.8)	2.3 (1.7 to 3.0)	1.8 (1.5 to 2.1)	<.0001
Urban T21 region	3.3 (2.9 to 3.7)	4.5 (4.1 to 5.0)	1.2 (0.7 to 1.8)	1.4 (1.1 to 1.9)	.01
Rural non-T21 region	2.8 (2.5 to 3.0)	5.6 (5.3 to 6.0)	2.9 (2.4 to 3.3)	2.7 (2.4 to 3.1)	<.0001
Rural T21 region	2.0 (1.3 to 2.8)	5.3 (4.2 to 6.4)	3.3 (2.0 to 4.6)	2.8 (2.3 to 3.4)	<.0001
Interaction of Year X Urbanicity-T21 Group	—	—	—	—	<.0001
Graders = 10 or 12 (n = 56 ,038)	—	—	—	—	—
Urban non-T21 region	14.0 (13.1 to 14.9)	20.4 (19.5 to 21.3)	6.4 (5.1 to 7.7)	1.8 (1.7 to 1.9)	<.0001
Urban T21 region	23.9 (22.8 to 25.1)	22.5 (21.5 to 23.5)	−1.4 (−3.0 to 0.1)	1.0 (0.8 to 1.2)	.96
Rural non-T21 Region	11.2 (10.6 to 11.7)	22.9 (22.2 to 23.6)	11.7 (10.8 to 12.6)	3.2 (3.1 to 3.3)	<.0001
Rural T21 region	13.0 (11.3 to 14.7)	17.5 (15.5 to 19.6)	4.5 (1.9 to 7.2)	1.7 (1.0 to 2.8)	.046
Interaction of Year X Urbanicity-T21 Group	—	—	—	—	<.0001

We identified a significant interaction between year (2018 and 2019) and urbanicity-T21 group (urban and non-T21, urban and T21, rural and non-T21, and rural and T21). Then we reported changes in e-cigarette use and aORs within each group. The model was adjusted by sex, grade, race and/or ethnicity, current cigarette smoking, current other tobacco use, parental education, and language used most often at home. —, not applicable.

[a] Multivariable logistic regression was performed to examine the changes in e-cigarette use (dependent variable), in which the survey year 2018 serves as the reference. We created a 4-category variable (urban and non-T21, urban and T21, rural and non-T21, and rural and T21) and tested the interaction between this variable and year.

educating youth about the risk for addiction associated with using e-cigarettes.[31] The rapid increase in e-cigarette use among rural youth may contribute to greater tobacco use and ultimately exacerbate existing health disparities experienced by rural communities.[32] Tailored strategies and evidence-based prevention programs are needed to educate youth about the harmfulness of e-cigarette use and reduce youth e-cigarette use, especially for rural adolescents.

In our study, researchers also found some evidence in support of T21 policies. In 2015, the National Academy of Medicine (formerly known as the Institute of Medicine) concluded that nationwide adoption of T21 would result in a 25% reduction in tobacco use by those aged 15 to 17 years and a 12% reduction in population smoking prevalence over time. In our study, we found a smaller increase in current e-cigarette use in T21 areas than in non-T21 areas. The only group for whom e-cigarette use did not significantly increase was youth in urban T21 areas, in which there was a 0.1% decrease in comparison to a 3.9% increase for youth in urban non-T21 areas. In rural areas, although current e-cigarette use increased significantly, the increase in T21 areas was less than half that in non-T21 areas (3.0% vs 7.1%). These findings suggest that T21 may curb increases in e-cigarette use among youth because there was a ∼4% lower absolute rate of uptake of e-cigarettes in both urban and rural areas in T21 regions than in non-T21 regions. Although encouraging, the effects of T21 policies in this study may have been limited by the relatively recent implementation of the ordinances in Kansas because a majority of T21 ordinances were passed from late 2015 to early 2017.[19] Both public knowledge and enforcement efforts may improve over time and further increase the impact of T21. The existing T21 policies were also implemented in a way that differed by geographic region,[33] and the gaps in T21 coverage were especially high in rural areas and other regions with weak tobacco control policies. In December 2019, the US Congress passed a federal law raising the minimum age to purchase all tobacco products from 18 to 21 years nationwide.[34] In future studies, researchers should examine whether a nationwide T21 policy could reduce e-cigarette use among youth, especially among those in rural areas.

This study is subject to several limitations. First, the KCTC Student Survey data are cross-sectional; thus, the causal inference cannot be established. Second, the data are based on 1 state (Kansas), and our findings might not be generalizable to other states. However, the prevalence of youth smoking in Kansas is close to the national average,[35] and Kansas has a mix of urban and rural areas and sufficient demographic diversity[36] to explore the social-demographic impacts. We did not

need to include other tobacco policies in the analyses because there were few changes in Kansas during the study period. For instance, the Kansas Indoor Clean Air Act went into effect on July 1, 2010, which prohibits smoking in most indoor locations. There were no variations in smoke-free legislation in Kansas.[37] There were also no bans on flavored tobacco products and no change in cigarette tax in Kanas during the study period.[38] Third, the results might not be generalizable to all school-aged youth and all middle and high school students in Kansas. Nevertheless, the KCTC Student Survey was used to collect data from students who attended both public and private schools. The survey uses a census approach, open to all schools in Kansas, and thus sample weighting was not required. Fourth, students were classified as being in a T21 or non-T21 area by using their school location, which may not have always corresponded with where they lived. Some youth responses may therefore have been misclassified. In addition, cities and towns in Kansas that enacted T21 legislation may be socioeconomically or politically different from those that did not. However, we adjusted for multiple covariates in the regression model to account for sociodemographic differences. Finally, retail compliance of underage sale laws was not assessed in this study because of limited data, and we could not account for potential mail delivery; only cigarettes and smokeless tobacco are currently classified as nonmailables,[39] and mail purchase of e-cigarettes may be particularly common among rural students.

Despite these limitations, researchers in this study reported marked disparities in the increase of youth e-cigarette use, with a much larger recent increase in rural areas. There is also some indication that T21 policies may curb increases in e-cigarette use among youth in both rural and urban settings. Continuous efforts to reduce e-cigarette use, especially in rural areas, are critically needed.

ABBREVIATIONS

aOR: adjusted odds ratio
CI: confidence interval
e-cigarette: electronic cigarette
KCTC: Kansas Communities That Care
RUCA: rural–urban commuting area
T21: Tobacco 21

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