Preventive Medicine Reports 12 (2018) 75–78

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Short communication

A new measure of youth cigarette smoking

Kenneth E. Warner

Dept. of Health Management and Policy, School of Public Health, University of Michigan, 1415 Washington Heights, Ann Arbor, MI 48109-2029, USA

ARTICLE INFO

Keywords:
Cigarette smoking
Youth
Students
Prevalence
Measurement

ABSTRACT

American students' 30-day smoking prevalence has decreased dramatically over the past two decades. The frequency of smoking within the 30-day measure has shifted from heavy smoking (> 1/2 pack/day) toward light smoking (< 1 to 5 cigarettes/day). 30-day prevalence thus understates the extent of the decline in youth smoking. To capture this shift toward less frequent smoking among the decreasing proportion of students who smoke, I develop a new index: the average number of cigarettes smoked per student per day (ACSD), using data from Monitoring the Future. To calculate ACSD I assign a specific number of cigarettes to each of 7 response options to the question, "How frequently have you smoked cigarettes during the past 30 days?" Response options range from "not at all" (assigned 0 cigarettes) to "two packs or more per day" (assigned 45 cigarettes). I then multiply these estimates by the proportion of students giving each response option. Summing across the 7 categories produces the ACSD for that survey year. I then compare time trends in 30-day prevalence and ACSD. From the mid-1990s to 2016, 30-day smoking prevalence among 12th graders declined 71.3%, while ACSD dropped 83.9% ($p < 0.001$). The figures were 84.0% and 90.6% ($p < 0.001$) for 10th graders and 87.4% and 89.0% for 8th graders ($p < 0.05$). Sensitivity analysis supports the finding that ACSD has decreased more than 30-day prevalence over time for both 10th and 12th grades. ACSD provides a new measure of the decline in youth smoking to complement the traditional measure of 30-day prevalence.

1. Introduction

In the United States, the standard definition of youth cigarette smoking is 30-day prevalence, i.e., whether a respondent has smoked at least one cigarette in the past 30 days. Virtually all discussions of youth smoking have adopted this measure in evaluating trends over time in adolescent smoking. As a public health surveillance tool, it is the youth equivalent of adult smoking prevalence. While data are now available from multiple surveys, the longest standing, Monitoring the Future (MTF), has evaluated smoking by students for over 40 years (Miech et al., 2018).

Recent research has demonstrated a limitation of the 30-day measure: over time, the intensity of smoking – within the 30-day window – has declined significantly. Using data from the 1991–2009 national Youth Risk Behavior Surveys, Jones et al. (2011) reported that from 1991 to 2009, among 9th–12th grade students who smoked, the percentage of light smokers (< 1–5 cigarettes/day) increased from 67.2% to 79.4%, while heavy smokers (≥11 cigarettes/day) decreased from 18.0% to 7.8%. With MTF data for 1975–2013, Kozlowski and Giovino (2014) found that among high school seniors who smoked, the percentage smoking daily decreased 29% from 1975 to 2013 and the percentage smoking ≥10 cigarettes/day dropped 40%. The authors concluded that "Additional measures of frequency and intensity of use of cigarettes and other tobacco/nicotine products need to be more regularly reported." In 2015, also using MTF data, I reported that four measures of smoking intensity dropped over time in 8th, 10th, and 12th grades. The decrease increased as one moved from the least intensive measure (lifetime ever-smoking) to the most (≥one-half pack of cigarettes/day). For the two most intensive measures, daily smoking and ≥one-half pack/day, the decreases exceeded 75% for all three grades (Warner, 2015).

These studies imply that, by missing youth's declining smoking intensity, the change over time in 30-day prevalence understates smoking's decrease among America's students. This paper derives a new measure intended to complement 30-day prevalence, to more closely reflect changes in youth smoking.

2. Methods

2.1. Data source

MTF is an annual survey of students' drug knowledge, attitudes, and use (Johnston et al., 2018). Nearly 44,000 8th, 10th, and 12th grade students in 360 schools participate. MTF has covered 12th graders since

E-mail address: kwarner@umich.edu.

https://doi.org/10.1016/j.pmedr.2018.08.013
Received 11 May 2018; Received in revised form 23 July 2018; Accepted 26 August 2018
Available online 28 August 2018

1975 and 8th and 10th graders since 1991. I use data on all years through 2016, available in the spreadsheet in the supplementary materials. (MTF has published 2017 data on 30-day and daily smoking (Miech et al., 2017) but not yet for the more detailed 30-day categories described immediately below.)

The present study uses the following question: "How frequently have you smoked cigarettes during the past 30 days?" Response options are "not at all," "less than one cigarette per day," "one to five cigarettes per day," "about one-half pack per day," "about one pack per day," "about one and one-half packs per day," and "two packs or more per day."

2.2. Development of new index

I weight the percentage responding to each of the response options by an estimate of the average number of cigarettes within each, for each grade and for all years. This creates a new index: the average number of cigarettes smoked per student per day (ACSD). For example, if in a given year 3.5% of 12th graders smoked about one-half pack/day (10 cigarettes), their contribution to that year's ACSD would be $0.035 \times 10 = 0.35$ cigarettes. I sum the same calculations for each of the 7 response options, yielding the ACSD for 12th graders in that survey year.

MTF does not ask respondents the specific number of cigarettes they smoke. As such, I estimate an average response. For the base-case analysis, I assume the following: For students who smoke < 1 cigarette/day, I assume the typical student smokes one cigarette every 5 days (0.2/day). I assume the typical student reporting 1–5 cigarettes smokes 2.5 cigarettes/day. For approximately one-half pack/day, I assume 10 cigarettes; for 1 pack, 20 cigarettes; for 1.5 packs, 30 cigarettes; and for ≥2 packs, 45 cigarettes. These estimates apply in all years. (See column 2 of Table S-1 in the supplementary material.)

2.3. Statistical analysis

To test the significance of the change in the difference between ACSD and 30-day prevalence over time, I performed linear regressions with quadratic trends on the differences in the annual percentage changes in the two indices from the inception of each grade's survey to 2016. From the estimated regression functions, I estimated the difference in percentage decline between the two variables and the 95% confidence interval around the 2016 estimate compared to the initial year's estimate, which in turn yielded *p* values reported below. I did the same for a beginning year of 1996 for 8th and 10th graders and 1997 for 12th graders. 1996 was the year of peak 30-day prevalence for 8th and 10th graders. For 12th graders 30-day prevalence peaked in the first survey year, 1976, at 38.8%, then decreased, stabilized at 29–30%, and rose again beginning in 1994, peaking at 36.5% in 1997. For all three grades, prevalence declined almost annually from 1996 (1997 for seniors) through 2016.

2.4. Sensitivity analysis

My estimates of the average numbers of cigarettes per response option could be wrong. Further, they might change over time. For example, as students shift from higher-frequency categories (i.e., ≥one-half pack/day) to lower-frequency categories (≤1–5 cigarettes/day), the average number of cigarettes per category might fall as well. Alternatively, the average might fall for higher-frequency categories and increase for lower. While it seems unlikely, remaining smokers in higher-frequency categories might each smoke more cigarettes than those who "dropped down" to lower-frequency categories.

To address these possibilities, I perform a sensitivity analysis in which I assume that the average within-category number of cigarettes *rises* from 1996 to 2016 (see column 3 of supplementary Table S-1). I assume, for example, that the pack/day smoker's average daily consumption increases annually by 0.2 cigarettes from 20 in 1996 to 24 in 2016. For the years prior to 1996, daily cigarettes per category correspond to the rate in the post-1996 period closest to the same prevalence. To illustrate, in 1987, 5.53% of 12th graders reported smoking about one-half pack/day. In the sensitivity analysis, that prevalence was assigned 10.5 cigarettes per day because the steady 0.2 cigarette annual increase from 1996 to 2016 had the same value (10.5 cigarettes) in 2001 when 5.54% of 12th graders reported smoking one-half pack/day.

If the base-case ACSD index falls more rapidly over time than 30-day prevalence – indicating that youth smoking has decreased more than 30-day prevalence implies – the sensitivity analysis will determine whether this finding is sensitive to the specific estimates of cigarettes per category. Increasing the number of cigarettes per category from 1996 to 2016 will necessarily produce a higher average number of cigarettes, increasing annually after 1996, than will the base case. If the ACSD in the sensitivity analysis falls more gradually than does 30-day prevalence, that will indicate that the new index is less likely to represent a meaningful new contribution to measuring youth smoking. In contrast, if, like the base case, the ACSD in the sensitivity analysis falls more rapidly than does 30-day prevalence, that will indicate that the new index captures the decrease in youth smoking more effectively than does 30-day prevalence.

3. Results

Fig. 1 shows 30-day smoking prevalence and the base-case ACSD for high school seniors from 1976 to 2016. Smoking prevalence dropped 73%, from 38.8% in 1976 to 10.5% in 2016. ACSD dropped 88%, from 3.42 in 1976 to 0.42 in 2016. The difference is significant at $p < 0.001$. Figs. S-1 and S-2 in the supplementary material show similar if less substantial differences for 8th and 10th grades from 1991, the year of first data collection for these grades. The difference is statistically significant at $p < 0.001$ for 10th grade but statistically nonsignificant for 8th grade ($p = 0.086$).

Table 1 presents 30-day prevalence and ACSD for 8th and 10th grades from 1996 to 2016 and from 1997 to 2016 for 12th grade, indicating the percentage decrease for each (last line of the table). The table provides results for the base case and the sensitivity analysis. Findings include:

- For all three grades, the percentage decreases in all of the measures of smoking are very large, from 71.3% (12th graders' 30-day prevalence) to 90.6% (the base-case ACSD for 10th graders).
- For all three grades, the base-case ACSD index falls by more than does 30-day prevalence. The difference is greatest for 12th graders, smallest for 8th graders. The differences are statistically significant

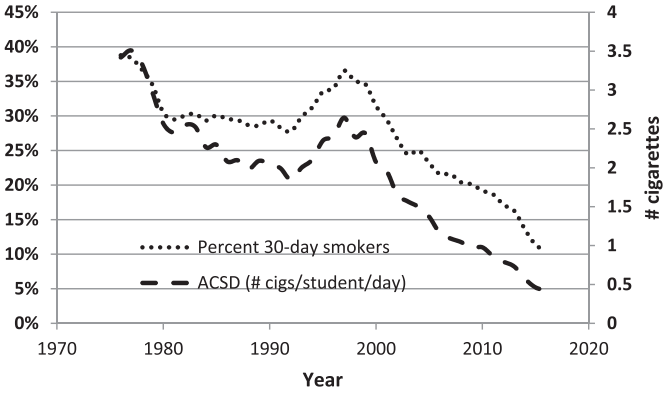

Fig. 1. 30-day smoking prevalence (%) and ACSD (average number of cigarettes per student per day), 12th graders, U.S., 1976–2016.
Source: Monitoring the Future.

Table 1
30-day smoking prevalence and ACSD (average number of cigarettes per student per day), 8th, 10th, and 12th graders, U.S., 1996 (8th and 10th graders) or 1997 (12th graders) and 2016.

Year	8th grade			10th grade			12th grade		
	30-day prevalence	Cigarettes/day/student*		30-day prevalence	Cigarettes/day/student*		30-day prevalence	Cigarettes/day/student*	
		Base case	Sensitivity analysis		Base case	Sensitivity analysis		Base case	Sensitivity analysis
1996 (8th and 10th grades) 1997 (12th grade)	21.0%	0.952	0.952	30.4%	1.790	1.790	36.6%	2.645	2.672
2016	2.7%	0.105	0.125	4.9%	0.169	0.204	10.5%	0.425	0.516
Change	−87.4%	−89.0%**	−86.9%	−84.0%	−90.6%***	−88.6%	−71.3%	−83.9%***	−80.7%

* The 1996 and 1997 cigarettes/day/student are necessarily the same in each grade for the base case and the sensitivity analysis, as deviations from the base case in the sensitivity analysis occur before and after the first year.
** $p < 0.05$ for difference from 30-day prevalence.
*** $p < 0.001$ for difference from 30-day prevalence.

at $p < 0.05$ for 8th grade and $p < 0.001$ for 10th and 12th grades.
- For 10th and 12th grades, even the sensitivity analysis decreases by more than 30-day prevalence. For 8th grade, the sensitivity analysis decreases slightly less than 30-day prevalence. The effects of the sensitivity analysis in 12th grade can be seen in Fig. S-3 in the supplementary material.

4. Discussion

4.1. The findings in context

America's 20-year decline in youth smoking is of breathtaking magnitude. In 1996 nearly a fifth of 8th graders had smoked at least one cigarette in the past 30 days. In 2016 only 2.7% had, a decrease of 87.4%. 30% of 10th graders and 37% of 12th graders had smoked in 1996 and 1997, respectively, but only 4.9% and 10.5% did so in 2016. As large as these decreases are, ACSD decreases even more rapidly for all three grades. The largest difference, for 12th graders, shows an ACSD decrease in smoking 18% larger than the decline in 30-day prevalence. The increase in the decline is smaller for 8th graders (2.3%) and 10th graders (7.9%). With the sensitivity analysis assumptions, the new index continues to reflect a larger decrease in smoking than does 30-day prevalence for 10th and 12th grades, but not for 8th grade.

4.2. Limitations

The ACSD relies on estimating the number of cigarettes per category of daily smoking. The sensitivity analysis offers some assurance that the new index "works" in that even very pessimistic (and likely unrealistic) estimates result in smoking decreases larger than for 30-day prevalence for 10th and 12th graders. Any set of realistic estimates is likely to conclude that the ACSD index characterizes the decline in smoking better than does 30-day prevalence alone.

It is reassuring to note that of the 7 options in response to MTF's daily smoking frequency question, 4 imply specific estimates: "not at all" (0), "about one-half pack per day" (10), "about one pack per day" (20), and "about one and one-half packs per day" (30). Only 3 require more arbitrary assumed values: "less than one cigarette per day," "one to five cigarettes per day," and "two packs or more per day." The first two of these involve very small numbers, whatever assumptions are made; as such, the assumed values cannot influence the overall average much. The third applies to a tiny fraction of the population, so even if the estimate is off by a few cigarettes, that cannot have a substantial impact on the overall daily consumption estimate. (For 12th graders, who had the highest rate of smoking two packs or more per day, that rate peaked at < 0.5% in 1995 and was < 0.3% in 2016. For 8th and 10th graders, it was around 0.1% in 2016.)

4.3. The importance of reductions in daily cigarette smoking

Reductions in cigarettes smoked daily by youth matter only if the reductions lead to less established smoking during adulthood; or, if not, if continued (adult) smoking at low levels reduces overall risk of smoking-produced morbidity and mortality.

Dutra and Glantz (2018) recently found a dose-response relationship between intensity of adolescent smoking and subsequent likelihood of smoking during young adulthood. While youth who smoked at all had a higher likelihood of young adult smoking than those who did not smoke, those who smoked the least (1–5 cigarettes/month) had a substantially lower risk of smoking during young adulthood than did more intensive youth smokers (e.g., daily smokers). Because the study's subjects were adolescents in the late 1990s, when youth smoking peaked, we cannot know its precise relevance for contemporary youth. However, if the relationship holds today, the shift toward lower-intensity smoking among youth, reflected in ACSD, may lead to less established smoking during adulthood.

The trend toward fewer cigarettes/day applies to adults as well as adolescents. However, even light smoking (1–9 cigarettes/day) greatly increases mortality risk. Some evidence suggests that the duration of smoking may be more important than intensity (daily consumption) in overall mortality (U.S. Department of Health and Human Services, 2014). Thus, understanding how reduced daily smoking among youth affects subsequent adult smoking is an important subject for future research. ACSD provides a new measure to complement 30-day prevalence in future evaluations of this critically important relationship.

The decreased youth cigarette smoking would be less encouraging were it offset by increasing use of other tobacco products (OTPs). Fortunately, OTP data are generally consistent with data on cigarettes. With one exception, however, OTP data are available only for recent years. MTF has covered smokeless tobacco since 1991. For all three grades, smokeless use peaked in the mid-1990s, as did smoking, fluctuated thereafter, and began declining during the present decade, reaching its lowest level ever in 2017 for 8th and 12th grades and 2016 for 10th grade. MTF data since 2014 on large cigars, flavored little cigars, and regular little cigars show use of all three products declining, reaching their lowest prevalence in all three grades in 2016 or 2017 (Miech et al., 2017, table 3).

The National Youth Tobacco Survey (Jamal et al., 2017) estimates 30-day prevalence for 2011–16 for smokeless tobacco, cigars, hookah, pipe tobacco, and bidis. All have generally declined for both high school and middle school students. The only nicotine-yielding product category that has increased in recent years is electronic cigarettes.

Researchers debate whether e-cigarette use increases or decreases cigarette smoking (Soneji et al., 2017; NASEM, 2018; Levy et al., 2018).

5. Conclusion

Documenting decreases in smoking frequency within 30-day prevalence, Jones et al. (2011), Kozlowski and Giovino (2014), and Warner (2015) all found that 30-day prevalence failed to capture the full extent of smoking's decrease among America's students. The present study adds a specific quantitative assessment tool to the previous studies' conclusions. Weighting students' responses to the frequency of their smoking within the past 30 days by the approximate number of cigarettes in each of the answer options provides a new measure of how much youth smoking has changed over time.

30-day prevalence fails to distinguish students who smoke 1 cigarette a month from those who smoke a pack/day. ACSD, measuring students' average daily cigarette consumption during the month, has the virtue of considering both the fact of smoking and its intensity. That strength is a weakness as well, however, in that it spreads cigarette consumption over all students, not just smokers. As such, it is useful to consider both smoking prevalence and ACSD in describing the extent of smoking among students.

Although imperfect, ACSD adds a dimension of smoking intensity to the long-standing tradition of defining youth smoking solely by 30-day prevalence. It demonstrates quantitatively that the impressive decline in 30-day smoking prevalence understates the degree to which America's students have been rejecting smoking.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

The author declares there are no conflicts of interest.

Acknowledgment

I am grateful to Dr. Richard Miech, Principal Investigator on Monitoring the Future, for providing the data used in this analysis and to Dr. David Mendez for assistance with the statistical analysis.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2018.08.013.

References

Dutra, L.M., Glantz, S.A., 2018. Thirty-day smoking in adolescence is a strong predictor of smoking in young adulthood. Prev. Med. 109 (April), 17–21. https://doi.org/10.1016/j.ypmed.2018.01.014.

Jamal, A., Gentzke, A., Hu, S.S., et al., 2017. Tobacco use among middle and high school students — United States, 2011–2016. MMWR Morb. Mortal. Wkly Rep. 66, 597–603. https://doi.org/10.15585/mmwr.mm6623a1.

L.D. Johnston, R.A. Miech, P.M. O'Malley, et al. Monitoring the Future National Survey Results on Drug Use: 1975–2017: Overview, Key Findings on Adolescent Drug Use. Ann Arbor: Institute for Social Research, The University of Michigan. http://www.monitoringthefuture.org/pubs/monographs/mtf-overview2017.pdf (2018). Accessed 10th May 2018.

Jones, S.E., Kann, L., Pechacek, T.F., 2011. Cigarettes smoked per day among high school students in the U.S., 1991–2009. Am. J. Prev. Med. 41, 297–299.

Kozlowski, L.T., Giovino, G.A., 2014. Softening of monthly cigarette use in youth and the need to harden measures in surveillance. Prev. Med. Rep. 1, 53–55.

Levy, D.T., Warner, K.E., Cummings, K.M., et al., 2018. Examining the Relationship of Vaping to Smoking Initiation Among US Youth and Young Adults: A Reality Check. Working Paper. Lombardi Comprehensive Cancer Center, Georgetown University, Washington, D.C.

Miech, R.A., Schulenberg, J.E., Johnston, L.D., et al., 2017. National adolescent drug trends in 2017: findings released. Tables 3 and 4. In: Monitoring the Future: Ann Arbor, MI, . http://www.monitoringthefuture.org/data/17data.html#2017data-drugs (2018). Accessed 29th April 2018.

Miech, R.A., Johnston, L.D., O'Malley, P.M., Bachman, J.G., Schulenberg, J.E., Patrick, M.E., 2018. Monitoring the Future National Survey Results on Drug Use, 1975–2017: Volume I, Secondary School Students. Institute for Social Research, The University of Michigan, Ann Arbor Available at. http://monitoringthefuture.org/pubs.html#monographs Accessed July 14, 2018.

National Academies of Sciences, Engineering, and Medicine, 2018. Public Health Consequences of E-cigarettes. The National Academies Press, Washington, D.C.. https://doi.org/10.17226/24952.

Soneji, S., Barrington-Trimis, J.L., Wills, T.A., et al., 2017. Association between initial use of e-cigarettes and subsequent cigarette smoking among adolescents and young adults: a systematic review and meta-analysis. JAMA Pediatr. 171 (8), 788–797.

U.S. Department of Health and Human Services, 2014. The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General. Chapter 11. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, Atlanta, GA. Printed with corrections, January 2014. Available at https://www.surgeongeneral.gov/library/reports/50-years-of-progress/full-report.pdf. Accessed July 14, 2018.

Warner, K.E., 2015. The remarkable decrease in cigarette smoking by American youth: further evidence. Prev. Med. Rep. 2, 259–261.