Impact of Electronic Nicotine Delivery Systems and Other Respondent Characteristics on Tobacco Use Transitions among a U.S. National Sample of Women of Reproductive Age

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Abstract

Background—Identifying predictors of tobacco use patterns that differ in harm among reproductive-aged women may inform efforts to protect women and children against adverse health impacts of tobacco use.

Methods—Changes in tobacco use patterns were examined among women (18–49 years) who completed Wave 1 (W1) and Wave 2 (W2), or W2 and Wave 3 (W3) of the U.S. Population Assessment of Tobacco and Health (PATH, 2013–2016) study, and were using cigarettes, filtered cigars and/or cigarillos in the first wave over which data were included for that respondent (Time 1; T1). We examined the proportion of respondents whose tobacco use transitions from T1 to Time 2 (T2) were harm-maintaining (continued using combusted tobacco), harm-reducing (transitioned to electronic nicotine delivery systems (ENDS), or harm-eliminating (quit tobacco). Multinomial logistic regressions (with harm-maintaining as the baseline category) were conducted to examine associations between ENDS use, demographic, and psychosocial characteristics with each transition.

Results—A majority of women (83%) exhibited harm-maintaining transitions, followed by harm-eliminating (14.7%) and harm-reducing (2.3%) transitions. Use of ENDS at T1 was associated with increased odds of harm reduction and decreased odds of harm elimination. Younger women were more likely to make both harm-reducing and harm-eliminating transitions. Increased educational attainment, identifying as Black or Hispanic, increased psychiatric symptoms, and pregnancy were associated with harm elimination, whereas living at or above poverty was associated with harm reduction.

Conclusions—Study results contribute new information on the impact of ENDS, sociodemographic characteristics, psychiatric symptoms, and pregnancy on tobacco use transitions among reproductive-aged women.

1.   Introduction

The Centers for Disease Control and Prevention's (CDC) most recent estimate of cigarette smoking prevalence among U.S. adults is 14%, a 67% decrease since 1965 (Wang et al., 2018). Unfortunately, this decline has been unevenly distributed, with smoking prevalence remaining stable or even increasing over time in some subgroups (e.g., economically disadvantaged women) (Higgins and Chilcoat, 2009; Kurti et al., 2017). Women of reproductive age are a subgroup for whom smoking prevalence remains higher than the national average, with recent estimates indicating that 20.1% of reproductive-aged women are current cigarette smokers (Lopez et al., 2018). Moreover, nine in ten (41.1 million) tobacco users report using combustible products (Wang et al., 2018), which contribute overwhelmingly to tobacco-associated disease and death (United States Department of Health and Human Services, 2014), and pose unique risks for women (e.g., osteoporosis, early menopause, cervical cancer) (Borland and Segan, 2006). Pregnant women face these risks plus the risk of pregnancy complications, fetal growth restriction, premature delivery, and sudden infant death syndrome (Cnattingius, 2004; Dietz et al., 2010; Pauly and Slotkin, 2008). Thus, there remains a need for comprehensive, multipronged approaches to reducing combustible tobacco use in the U.S., particularly among vulnerable populations such as reproductive-aged women.

Whether electronic nicotine delivery systems (ENDS) have a role in reducing combusted tobacco use remains to be determined. A National Academies of Sciences' (NAS) review concluded that ENDS were less toxic and carcinogenic than combusted tobacco, and would reduce overall toxicant exposures if completely substituted for cigarettes (National Academies of Sciences Engineering Medicine, 2018). Thus, ENDS may provide a less harmful substitute for cigarettes among non-pregnant women of childbearing age who are unwilling or unable to quit smoking (United States Food and Drug Administration, 2018). With respect to pregnant women, neither the U.S. Preventive Services Task Force (USPSTF) nor the American College of Obstetricians and Gynecologists (ACOG) support the use of ENDS. In addition to the USPSTF's conclusion that there is insufficient evidence for ENDS

as a cessation aid (Siu & U.S. Preventive Services Task Force, 2015), an updated Committee Opinion released by ACOG also reminded providers that nicotine in any form poses health risks to a fetus (Committee on Obstetric Practice, 2017, p. e202). Although ACOG recommends screening for ENDS (Bhatnagar et al., 2014; Committee on Health Care for Underserved Women, 2011), only about half of providers report doing so (England et al., 2014), even though many reproductive-aged women use ENDS to reduce or quit smoking (Oncken et al., 2017). One prerequisite to evaluating the impacts of ENDS on tobacco use trajectories among women of childbearing age is to increase scientific knowledge about current ENDS use patterns, including whether and for whom ENDS facilitate transitioning away from combusted tobacco. Examining this question among reproductive-aged women may be particularly instructive, as they are at increased risk for multigenerational adverse health impacts should they continue using combusted tobacco while pregnant or parenting young children.

Several studies have examined prevalence and correlates of switching from conventional cigarettes to ENDS among U.S. adults (Anic et al., 2018; Berg et al., 2015; Kalkhoran et al., 2015; Park et al., 2017); however, we are unaware of comparable studies conducted among reproductive-aged women. Cross-sectional studies conducted among U.S. national samples of pregnant (Kurti et al., 2017) and non-pregnant (Lopez et al., 2018) women of reproductive age who completed Wave 1 (W1) of the Population Assessment of Tobacco and Health (PATH; 2013–2014) study indicated relatively high prevalence of using ENDS among former cigarette smokers; however, whether ENDS facilitated a transition away from cigarettes could not be ascertained in these cross-sectional studies. Two longitudinal studies conducted among reproductive-aged women who completed both W1 and Wave 2 (W2; 2014–2015) of PATH indicated that the most common transition among women using cigarettes alone or cigarettes plus ENDS in W1 was to cigarettes alone in W2 (Kurti et al., 2018a; Kurti et al., 2018b). However, these studies did not examine characteristics that predicted whether women continued smoking cigarettes, transitioned to ENDS, or quit all tobacco. Identifying those variables associated with continued use of cigarettes and/or other combusted products used like cigarettes (i.e., filtered cigars and cigarillos) (Reilly et al., 2018; Richardson et al., 2012), transitioning to ENDS, or quitting tobacco, could provide valuable insights to policymakers at the FDA. The FDA extended their authority to regulate ENDS in 2016 (United States Food and Drug Administration, 2016) and await research that informs regulatory policy surrounding these products. Such information may also be useful to physicians, cessation counselors, or others who work with reproductive-aged women in clinical settings.

The purpose of the present study is to address this knowledge gap by: (a) estimating across a one-year period what proportion of U.S. women of reproductive age who are current users of cigarettes, filtered cigars, and/or cigarillos continue using combusted tobacco (harm-maintaining), transition to exclusive ENDS use (harm-reducing), or discontinue all tobacco (harm-eliminating), and (b) identifying associations between ENDS use, demographic, and psychosocial characteristics with these three transitions.

2. Methods

2.1 Data Source

Data were obtained from the public use files of the first, second, and third waves of PATH, a longitudinal, nationally representative study of the U.S. non-institutionalized population aged > 12 years (N=45,971, Adult N=32,320) (Hyland et al., 2017; Kasza et al., 2017). Data from W1 were collected between September 2013 and December 2014 using address-based, area-probability sampling. W2 data were collected between October 2014 and October 2015, and Wave 3 (W3) data were collected between October 2015 and October 2016. This report is limited to women aged 18–49 years who completed two waves of PATH. Women < 18 were excluded to avoid any potential influences that legal restrictions on purchasing tobacco might have on patterns of use. Additional exclusion criteria included: (a) using products other than cigarettes, little cigars and/or cigarillos at the baseline wave for which data were included for each respondent (Time 1; T1), (b) missing data on any of the variables examined in this report (i.e., tobacco use, demographic characteristics, pregnancy) and (c) being pregnant at T1.

We began by identifying current users of cigarettes, little cigars, and/or cigarillos (all referred to as cigarette users below) in W1, following their tobacco use into W2. In order to allow a sufficiently large sample to examine each longitudinal transition of interest, we supplemented this sample of 3,371 women with 332 women who were current cigarette users in W2 but not in W1 and tracked their tobacco use into W3 (n=3,767 weighted %=26.8; 95%CI=25.7, 27.9). Supplementing the sample with these women who did not use cigarettes in W1 ensured that the additional women represented new respondents (thus no respondent's data were included twice in the present sample), while also permitting sufficient sample sizes for examining correlates of all three transitions of interest. The supplemental group of women were somewhat younger than those identified from W1, more likely to be women of color, higher educated, and less likely to have used illicit drugs in the past year.

The baseline wave for all women corresponded to the first wave over which data were included for that respondent (Time 1; T1). The follow-up time period (Time 2; T2) corresponded to the wave subsequent to their T1 interview. Thus, women whose baseline wave was W1 were collapsed with women whose baseline wave was W2. The 379 women (2.8%) who used tobacco product(s) other than cigarettes at T1 were excluded, as our interest was in tobacco use transitions among cigarette users. This group of excluded women reported using one or more non-combusted products (e.g., ENDS, snus, smokeless) in the absence of cigarettes. As expected among reproductive-aged women, the present sample included women who were not pregnant at their T1 interview, but were at T2 (n=197 weighted %=4.5, 95%CI=3.8, 5.1). Analyses were initially completed separately among pregnant and non-pregnant women, however the insufficient number of pregnant women who exhibited harm-reducing transitions (n=2) precluded our ability to examine respondent characteristics and conduct a regression for this outcome. Regressions conducted among non-pregnant women alone did not differ substantially from those conducted among a combined sample (see Supplementary Table 1).

Weighting procedures adjusted for varying selection probabilities and differential non-response rates, while appropriately accounting for the complex study design. The overall weighted response rate for W1 for adults was 74.0% with a weighted retention rate of 83.1% at W2, and 78.4% at W3. Among women who were pregnant at T2, the average gestational age (in weeks) was 21.7 (95%CI=19.9, 23.5; range=1–40 weeks).

2.2   Measures

2.2.1   Sociodemographics—Sociodemographic data included age, race/ethnicity, educational attainment, U.S. census region, and poverty status, based on household income, number of persons in the household, and the presence of people less than age 18 in the household.

2.2.2   Tobacco Product Use Categories—For all tobacco products, respondents were identified as current established or current experimental users according to PATH variable definitions (Hyland et al., 2017; Kasza et al., 2017). Current cigarette users included respondents who reported smoking > 100 lifetime cigarettes (i.e., established smokers) or < 100 lifetime cigarettes and smoking every day or some days at the time of survey completion (i.e., experimental smokers). Current users of traditional cigars, filtered cigars, cigarillos, ENDS, hookah, smokeless, snus, and pipes reported using these products regularly in the past (i.e., established users) or not regularly and using some days or every day at the time of survey completion (i.e., experimental users). Recall that this report is limited to women who reported current use of cigarettes at T1. Poly-users of additional tobacco products were included as long as they were also using cigarettes.

2.2.3   Tobacco Use Transitions—After determining women's use status for the above products at both T1 and T2, they were categorized into groups based on changes in their tobacco use across survey waves. The harm-maintaining group included women who continued using cigarettes at T2 either alone or with other tobacco products. Women who quit cigarettes but used other combusted tobacco at T2 were also categorized as harm-maintaining, consistent with research documenting significant toxicant exposure associated with any combusted tobacco use (Ali and Jawad, 2017; World Health Organization, 2008). This group included exclusive hookah users (n=30), dual users of hookah and ENDS (n=21) or hookah and pipes (n=1), and users of traditional cigars either with or without ENDS (n=1 and n=4, respectively). The harm-reducing group included women using ENDS alone at T2; the harm-eliminating group included women using no tobacco at T2.

2.2.4   Pregnancy—At W1, respondents < 50 years were asked if they had ever been pregnant, while the W2/W3 versions of this question asked about pregnancy in the previous 12 months. Women who responded affirmatively received a second question asking if they were currently pregnant, and if yes, to report their gestational age. Women who endorsed being pregnant at T2 were identified as pregnant in this report. As we were interested in the impact of becoming pregnant on tobacco use transitions, women endorsing pregnancy at T1 were excluded.

2.2.5   Other Substance Use—Alcohol use was defined as any alcohol consumption within the past year. Illicit drug use was defined as using at least one of the following in the past year: prescription drugs used without a prescription, marijuana, cocaine, crack, methamphetamine, heroin, inhalants, solvents, or hallucinogens.

2.2.6   Psychiatric Symptoms—Psychiatric symptoms were estimated using two subscales of the Global Appraisal of Individual Needs—Short Screener (GAIN-SS) (Dennis et al., 2006) that measure constructs associated with smoking: Internalizing (e.g., anxiety, depression) and Externalizing (e.g., hyperactivity, impulsivity). Both subscales present respondents with a specific symptom and ask them to identify how recently they experienced that symptom (e.g., past month, past year, never). One point is assigned for each symptom experienced in the past year, with Internalizing and Externalizing scores ranging from 0–4 and 0–5, respectively. Total scores of 0 suggest that respondents are unlikely to have a diagnosis, scores of 1 or 2 indicate a possible diagnosis, and scores > 3 indicate high probability of a diagnosis (Dennis, 2002).

2.3   Statistical Methods

Frequencies and percentages were generated across all respondents and were weighted to account for the complex sampling scheme, sampling probability, and differential non-response. Variance estimation was conducted as a variant of balanced repeated replication (Fay's method) using a predetermined value ε set to 0.3, recommended as the preferred procedure for the PATH study (Judkins, 1990; McCarthy, 1969).

We first examined ENDS use, demographic, and psychosocial characteristics among women using cigarettes at T1 overall, as well as separately among those who exhibited harm-maintaining, harm-reducing, or harm-eliminating transitions. We then calculated the overall proportion of women who made each transition, as well as the proportion of women using specific tobacco product(s) at T1 who exhibited each transition.

To identify correlates of each transition, we conducted multinomial logistic regression analyses among all women who were using cigarettes at T1. The dependent outcomes at T2 included continued use of cigarettes and/or other combusted tobacco (harm-maintaining), exclusive ENDS use (harm-reducing), and no tobacco use (harm-eliminating). The harm-maintaining group was the reference category for the logistic regression. Thus, odds ratios in the models represent the odds of each outcome compared to the odds of exhibiting a harm-maintaining transition adjusting for all other variables. Predictors in each regression included ENDS use, demographic and psychosocial characteristics, and pregnancy status. As noted above, these same analyses were repeated excluding pregnant women (see Supplementary Table 1).

All analyses were conducted using SAS 9.4 software (SAS Institute, Cary, NC) and statistical significance was defined as $p < .05$ (2-tailed). Missing data on any variable resulted in case-wise deletion of that respondent, resulting in the deletion of 1.8% of the respondents.

3. Results

3.1 Sample Characteristics

Table 1 shows respondent characteristics at T1 overall and separately within women who exhibited each transition. Overall, nearly a quarter (22.4%) of the sample reported using ENDS at T1. Slightly over half (55.3)% were between 18–34 years, with 66.8% being White, and 45.1% having a maximum educational attainment of graduating high school or less. Pregnant women comprised 4.5% of the sample. Higher proportions of women lived in the South (39.6%) or Midwest (24.0%) relative to the Northeast or West. Nearly half (45.5%) lived below the poverty level, with 78.1% endorsing alcohol use and 37.4% endorsing illicit drug use in the past year. Use of combusted tobacco other than cigarettes at T1 was endorsed by 16.6%. Average internalizing (2.0) and externalizing (1.1) scores indicated possible psychiatric diagnoses. Several respondent characteristics differed between women who exhibited each transition (e.g., ENDS use, education, pregnancy status); however, characteristics that were significantly associated with each transition of interest are addressed subsequently in the logistic regression analyses.

3.2 Longitudinal Transitions in Patterns of Tobacco Use

Among the overall sample of T1 cigarette smokers, 83.0% continued using cigarettes and/or other combusted tobacco at T2 (harm maintenance), 2.3% transitioned to ENDS (harm reduction), and 14.7% quit using tobacco (harm elimination) (Table 2).

This pattern of the vast majority being in the harm maintenance category at T2 dominated independent of the specific tobacco product(s) used at T1. Among women exclusively using cigarettes at T1 (65.9%), 82.8% continued using them and/or other combusted tobacco at T2, with the remaining 2.9% and 15.4% in the harm-reducing or harm-eliminating categories, respectively. Among women using cigarettes plus ENDS at T1 (16.8%), 87.3% were categorized as harm-maintaining, 4.1% as harm-reducing, and 8.6% as harm-eliminating. For poly-users of cigarettes, ENDS, and other tobacco at T1 (11.7%), 84.4% were categorized as harm-maintaining as opposed to harm-reducing (3.3%) or harm-eliminating (12.3%). Finally, among the 5.7% of women using cigarettes and other tobacco products excluding ENDS at T1, 77.7% were categorized as harm-maintaining at T2, with the remaining 1.6% and 20.8% categorized as harm-reducing and harm-eliminating, respectively.

3.3 Logistic Regression Modeling

When controlling for other characteristics in the multinomial logistic regression analysis, use of ENDS at T1, various demographic and psychosocial characteristics, and pregnancy remained statistically significant predictors of tobacco use transitions (Table 3). More specifically, use of ENDS at T1 increased the odds of harm reduction, while also decreasing the odds of harm elimination. Age was also a significant predictor of both harm-reducing and harm-eliminating transitions, with women age 18–24 being more likely to exhibit each of these transitions than their 35–49 year old counterparts.

Poverty status was a significant predictor of harm reduction only, with those at or above the poverty level having increased odds of transitioning to ENDS than those living below the poverty level. In contrast to the few characteristics associated with harm reduction, education, race/ethnicity, psychiatric symptoms, and pregnancy were each significant, independent predictors of harm elimination. More specifically, those with a high school education or greater had increased odds of quitting tobacco compared to those who did not complete high school. Non-Hispanic Blacks and those of Hispanic ethnicity were more likely to quit tobacco than those identifying as Non-Hispanic White. Reporting a higher number of externalizing symptoms was associated with increased odds of quitting tobacco. In contrast, reporting more internalizing symptoms was associated with decreased odds of quitting. Pregnancy was also associated with increased odds of quitting all tobacco.

4. Discussion

To our knowledge, the present study represents the first examination of characteristics that distinguish women whose longitudinal transitions in tobacco use can be conceptualized as maintaining, reducing, or eliminating harm. The study results indicate that the vast majority of reproductive-aged women using cigarettes continue using them across time, a finding that is consistent with prior longitudinal studies highlighting the durability of cigarette use relative to use of other tobacco products (Kurti et al., 2018a; Kurti et al., 2018b). The current study also extended these previous findings by elucidating predictors of specific tobacco use transitions, including novel information about the role of ENDS in these transitions. We make six points about these observations below.

First, dual use of cigarettes and ENDS was associated with both increased odds of transitioning to ENDS, and decreased odds of quitting tobacco entirely. With respect to U.S. public health implications, this pattern may be consistent with a policy of recommending to current cigarette smokers that they first attempt to discontinue all tobacco use. However, for those who are unable or unwilling to discontinue all use, transitioning to ENDS represents the next best option for reducing the risk of harm from continuing tobacco use. Although the apparent conflicting trends observed in this report may support the merits of policies that offer such a tiered recommendation, it is important that cigarette smokers who opt for ENDS avoid unregulated or "black market" products which may be associated with vaping-related pulmonary illness (Christiani, 2019; Layden et al., 2019). Future research should examine whether those women who exhibited harm-reducing transitions across two survey waves quit tobacco entirely in additional waves of PATH. Although a higher proportion of the women who were using ENDS at T1 continued using cigarettes at T2 (> 80%) versus transitioning to ENDS (3–4%), the positive impact of even a small number of women exhibiting harm-reducing transitions at the population level may be substantial. Indeed, a recent estimate of cost savings to state-level Medicaid programs if just 1% of adult smokers switched to ENDS was ~$2.8 billion (Belzer, 2017). Nonetheless, the present findings do not warrant recommending ENDS as a smoking cessation tool among this population in lieu of evidence-based approaches (e.g., nicotine replacement therapy, varenicline) (Ghosh and Drummond, 2017).

Second, the present results offer new information on how pregnancy influences tobacco use transitions. Pregnant women comprised 2.8% of harm maintainers, 1.3% of harm reducers, and 14.5% of harm eliminators. Additionally, the regression analyses indicated that pregnancy was a significant predictor of harm elimination, but not harm reduction. The finding that more pregnant women either quit tobacco entirely or continued smoking than transitioning to ENDS may be attributable to perceptions endorsed by pregnant women that ENDS are equally or more harmful and stigmatized during pregnancy than cigarettes (Nguyen et al., 2016). Related to this, pregnant women may not view ENDS as a viable approach to harm reduction if a quit attempt fails. It should be noted, however, that findings on this topic are mixed, with other studies indicating that pregnant women perceive ENDS as less harmful than cigarettes (Mark et al., 2015; Wagner et al., 2017). Future research on effects of ENDS versus cigarettes on fetal and infant health will inform which of these perceptions is more accurate. In addition, research conducted among postpartum women indicating an interest in using ENDS to reduce or quit smoking after childbirth suggests that examining ENDS as postpartum relapse prevention tools may be worthwhile (Bowker et al., 2018).

A third point worth noting is the consistency between the present study and research conducted among the general U.S. population of adult smokers. For example, higher proportions of women in the present sample exhibited harm-eliminating transitions (14.7%) versus harm-reducing transitions (2.3%), a pattern also observed among the general U.S. population (Adkinson et al., 2013; Grana et al., 2014; Vickerman et al., 2013). However, despite similar overarching patterns between the general population and the present sample of reproductive-aged women, there may be differences in those characteristics associated with harm reduction within each population. For example, the only variables associated with harm reduction in the current sample were using ENDS at T1, younger age, and living at or above the poverty level. In contrast, these plus additional variables including higher educational attainment, living in the South or West, and being partnered or married, predicted harm reduction in a recent study conducted among a U.S. national sample of adult smokers (Park et al., 2017). It is possible that those variables did not reach statistical significance in the present study due to the small sample of women who exhibited harm-reducing transitions. Alternatively, perhaps inclusion of ENDS/cigarette dual-users at T1 already accounted for any potential other characteristics to emerge as significantly predicting harm reduction. Future research is needed to clarify those variables associated with harm reduction in both the general U.S. population, and among reproductive-aged women specifically.

Fourth, the study findings have implications for tobacco regulatory science. For example, FDA must weigh the mixed results reported here and elsewhere regarding the ability of ENDS to simultaneously promote harm reduction, while also undermining efforts to quit using combusted tobacco entirely. On the one hand, the National Academies of Sciences concluded that ENDS would reduce toxicant exposures if completely substituted for cigarettes (National Academies of Sciences Engineering Medicine, 2018), and ENDS appeared to be a sufficient replacement for cigarettes among some proportion of women in the current sample. If ENDS are allowed to continue evolving, they may continue improving in terms of providing a desirable alternative to cigarettes. Misleading public health messages

that discourage switching, as well as FDA regulations that restrict ENDS evolution and make them uncompetitive with cigarettes, may postpone or deter harm-reducing transitions in tobacco use (Hajek, 2014). On the other hand, regulators must strike a careful balance between allowing attractive substitutes for cigarette smokers to emerge, while also curbing the production and marketing of products like the JUUL, which has exploded in popularity among youth (Willett et al., 2019). Although there are hopes that ENDS may have a place in FDA's vision of a comprehensive nicotine reduction policy, the role of ENDS in this context remains to be determined.

Fifth, the present results also have implications for tobacco control. The persistence and durability of tobacco use patterns involving cigarettes highlights the need for ongoing dedication to implementing comprehensive tobacco control programs at the national, state, and local levels, including tobacco price increases, anti-tobacco mass media campaigns, smoke-free laws, and barrier-free access to tobacco cessation counseling and approved medications (Wang et al., 2018). These efforts may benefit women aged 35–49 years in particular, as this age group had lower odds of both harm reduction and harm elimination than their 18–24 year old counterparts. These age differences may be driven by discrepancies in the length of smoking histories among women in each group, with women aged 18–24 years having spent less years smoking thereby perhaps being less dependent and having less difficulty substituting ENDS for cigarettes or quitting altogether. The finding that a considerable proportion of women using cigarettes also use ENDS highlights the need for healthcare providers to screen women for ENDS use alongside conventional cigarettes. At present, < 53% of providers report screening for non-combustible tobacco use (England et al., 2014), even though using ENDS may signal interest in quitting smoking and openness to using other quit methods (Ghosh and Drummond, 2017; Kalkhoran et al., 2015). Indeed, a recent report based on the Pregnancy Risk Assessment Monitoring System (PRAMS) indicated that 45.2% of women who used ENDS around the time of pregnancy used them to quit or reduce smoking (Kapaya et al., 2019). Although the perception that ENDS facilitate smoking reduction or cessation may be relatively common, the USPSTF has deemed the evidence supporting ENDS as a cessation aid to be insufficient (Siu and U.S. Preventive Services Task Force, 2015) and ACOG has raised concerns about the lack of data on health effects of ENDS during pregnancy (Committee on Obstetric Practice, 2017). It will be important for providers to stay abreast of USPSTF and ACOG reports so they are prepared to share updated knowledge and recommendations surrounding ENDS with their patients.

Though the current report adds to the existing evidence base, it has several limitations that merit mention. First, the relatively small number of women in the harm-reducing group reduced the reliability of estimates, produced wide CI's, and may have prevented us from observing significant relations in the regression analyses. A second limitation is the potential underreporting of tobacco use, particularly among pregnant women, which likely inflated quit rates (Dietz et al., 2011). Third, we did not examine women's self-reported reasons for using ENDS, thus we cannot conclude that ENDS are incompatible with harm elimination, as some women may have been using ENDS for reasons other than quitting smoking. ENDS have been shown to be as effective (Bullen et al., 2013; Caponnetto et al., 2013) or more effective (Hajek et al., 2019) than NRT in clinical smoking cessation trials, although their efficacy among reproductive-aged women requires further examination. Fourth, the PATH

survey does not inquire about covariates such as marital status, which may be associated with tobacco use (Lindstrom, 2010), and should therefore be examined in future studies. Finally, the current data were collected between 2013 and 2016, thus the role of ENDS in the transitions presented in this report may not reflect those that occur among women using newer ENDS devices like the JUUL.

Notwithstanding these limitations, the present study contributes new information on longitudinal transitions in tobacco use among a U.S. national sample of reproductive-aged women. Study results indicating that using ENDS increases the odds of harm reduction, while also decreasing the odds of harm elimination, deliver a mixed message on their utility in reducing smoking-related disease and death among this population. Although future research is needed, the present results are quite clear in adding to the already extensive literature demonstrating the persistence of conventional cigarette use. In this sense, they are an important reminder to researchers, clinicians, and policymakers to continue dedicating themselves to multipronged efforts spanning the domains of tobacco prevention, control, and regulatory science focused on reducing cigarette use among reproductive-aged women and other vulnerable populations.

5. Conclusions

The present study leveraged the longitudinal nature of the PATH survey to delineate those characteristics associated with exhibiting harm-maintaining, harm-reducing, or harm-eliminating transitions in tobacco use among a U.S. national sample of reproductive-aged women. Results of the study documented the persistence of combustible cigarette use, with a striking 83% of combustible tobacco users continuing to use combustibles across survey waves. While this finding certainly highlights the importance of ongoing tobacco regulatory science and tobacco control efforts focused on reducing conventional cigarette use, incorporating ENDS in these efforts may either enhance or undermine them, depending on the goal. Stated differently, ENDS may enhance efforts to move tobacco users from combusted to non-combusted products, while at the same time decreasing one's odds of quitting tobacco entirely.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Highlights

- Examined transitions in tobacco use among a U.S. national sample of reproductive-aged women

- 83% of reproductive-aged women maintained their use of combusted tobacco across time

- ENDS use increased odds of harm reducing transitions but decreased odds of quitting tobacco

- Further studies are needed to evaluate whether these associations are causal

Table 1.

Characteristics of females aged 18–49 years who used cigarettes at Time 1 (T1) overall and by longitudinal transitions in tobacco use patterns from T1 to Time 2 (T2). Data are from the Population Assessment of Tobacco and Health (PATH) study, United States, 2013–2016

Characteristic	Overall[a] (n = 3,767)	Harm-Maintaining (n = 3,156)	Harm-Reducing (n = 87)	Harm-Eliminating (n = 524)		
	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Chi-Square (df)	p
ENDS Use					24.26 (2)	<0.0001
Yes	22.4 (21.0, 23.8)	23.4 (21.9, 24.9)	37.9 (24.7, 51.1)	14.6 (11.3, 17.8)		
No	77.6 (76.2, 79.0)	76.6 (75.1, 78.1)	62.1 (48.9, 75.3)	85.4 (82.2, 88.7)		
Age					51.08 (4)	<0.0001
18–24 years	22.9 (21.5, 24.3)	20.3 (18.8, 21.8)	31.7 (21.6, 41.8)	36.1 (31.5, 40.6)		
25–34 years	32.4 (30.6, 34.1)	32.7 (30.7, 34.7)	3.5 (19.2, 41.8)	30.8 (26.0, 35.7)		
35–49 years	44.8 (42.6, 46.9)	47.0 (44.7, 49.4)	37.8 (25.6, 50.0)	33.1 (27.0, 9.1)		
Race/Ethnicity[a]					37.66 (6)	<0.0001
Non-Hispanic White	66.8 (64.9, 68.7)	68.5 (66.3, 70.7)	77.2 (67.5, 86.8)	55.5 (50.2, 60.7)		
Non-Hispanic Black	13.8 (12.3, 15.4)	13.7 (12.1, 15.3)	6.5 (0.8, 12.3)	15.5 (11.9, 19.0)		
Hispanic	13.3 (12.1, 14.5)	11.9 (10.4, 13.3)	11.6 (4.4, 18.9)	21.7 (17.3, 26.1)		
Other	6.1 (5.1, 7.1)	5.9 (4.8, 7.0)	4.7 (1.1, 8.3)	7.4 (4.0, 10.8)		
Education Level					54.70 (6)	<0.0001
< High School/GED	20.0 (18.5, 21.6)	21.7 (20.0, 23.3)	13.3 (5.8, 20.9)	11.7 (8.6, 14.8)		
High School Graduate	25.1 (23.2, 26.9)	25.6 (23.5, 27.6)	22.1 (12.2, 32.0)	22.6 (18.0, 27.3)		
Some college/ Associates	40.9 (38.8, 42.9)	40.0 (37.8, 42.2)	56.7 (45.6, 67.9)	43.0 (38.3, 47.7)		
> Bachelor's Degree	14.1 (12.3, 15.8)	12.7 (10.8, 14.6)	7.8 (2.0, 13.6)	22.7 (18.4, 27.0)		
Presence of Youth in the Home					2.46 (2)	0.29
Yes	56.1 (54.0, 58.2)	56.8 (54.4, 59.1)	51.7 (37.0, 66.4)	52.9 (48.7, 57.1)		
No	43.9 (41.8, 46.0)	40.9 (40.9, 45.6)	48.3 (33.6, 63.0)	47.1 (42.9, 51.3)		
U.S. Census Region					10.00 (6)	0.12
Northeast	18.2 (16.4, 20.1)	18.1 (15.9, 20.3)	14.6 (4.6, 24.5)	19.5 (14.9, 24.2)		
Midwest	24.0 (22.2, 25.8)	24.7 (22.8, 26.5)	21.0 (11.2, 30.8)	20.7 (15.4, 26.0)		
South	39.6 (37.2, 41.9)	40.0 (37.5, 42.6)	42.9 (29.1, 56.7)	36.2 (31.5, 40.9)		
West	18.2 (16.2, 20.2)	17.2 (15.2, 19.1)	21.6 (10.3, 32.9)	23.5 (18.5, 28.6)		
Poverty Status[b]					8.43 (2)	0.01
Below poverty level	45.5 (43.3, 47.6)	46.6 (44.2, 48.9)	31.9 (20.1, 43.6)	41.5 (36.6, 46.3)		
At above poverty level	54.5 (52.4, 56.7)	53.4 (51.1, 55.8)	68.1 (56.4, 79.9)	58.5 (53.7, 63.4)		
Alcohol Use[c]					1.41 (2)	0.49

Yes	78.1 (76.6, 79.7)	77.8 (76.1, 79.4)	82.9 (73.5, 92.2)	79.4 (75.0, 83.8)		
No	21.9 (20.3, 23.4)	22.2 (20.6, 23.9)	17.1 (7.8, 26.5)	20.6 (16.2, 25.0)		
Illicit Drug Use[d]					0.70 (2)	0.71
Yes	37.4 (35.6, 39.3)	37.8 (35.7, 40.0)	35.2 (23.7, 46.7)	35.7 (29.9, 41.5)		
No	62.6 (60.7, 64.4)	62.2 (60.0, 64.3)	64.8 (53.3, 76.3)	64.3 (58.5, 70.1)		
Other Combusted Tobacco Use					7.40 (2)	0.04
Yes	16.6 (15.1, 18.2)	15.9 (14.3, 17.6)	16.3 (8.1, 24.4)	20.6 (16.6, 24.7)		
No	83.4 (81.8, 84.9)	84.1 (82.4, 85.7)	83.7 (75.6, 91.9)	79.4 (75.3, 83.4)		
Pregnant at T2[e]					161.21 (2)	<0.0001
Yes	4.5 (3.8, 5.1)	2.8 (2.3, 3.2)	1.2 (0.0, 3.0)	14.5 (10.6, 18.5)		
No	95.5 (94.9, 96.2)	97.2 (96.8, 97.7)	98.8 (97.0, 100.0)	85.5 (81.5, 89.4)		
	Mean (95% CI)	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**F (df)**	
Psychiatric Status[f]						
Internalizing	2.0 (2.0, 2.1)	2.1 (2.0, 2.1)	2.3 (1.9, 2.7)	1.9 (1.7, 2.1)	2.90 (2,100)	0.06
Externalizing	1.1 (1.0, 1.1)	1.1 (1.0, 1.1)	1.3 (1.0, 1.6)	1.2 (1.0, 1.4)	2.51 (2,100)	0.09

Notes.

[a]The four racial/ethnicity categories (White, Black, Other, Hispanic) are mutually exclusive; persons identifying as Hispanic are categorized as such, regardless of race, "Other" includes non-Hispanic persons of two or more races and persons belonging to racial groups other than non-Hispanic White or non-Hispanic Black.

[b]Based on reported family income and poverty thresholds published by the U.S. Department of Health and Human Services.

[c]Self-reported alcohol use within the past year.

[d]Self-reported use of at least one of the following illicit drugs within the past year: marijuana, cocaine or crack, prescription drugs such as painkillers or sedatives used without a prescription, stimulants like methamphetamine or speed, or any other drugs such as heroin, inhalants, solvents, or hallucinogens.

[e]Endorsed being pregnant at the time of completing the PATH survey in either Wave 2 or Wave 3.

[f]Represents the average number of symptoms experienced in the past year reflecting a possible internalizing or externalizing psychiatric disorder (score ranges 0 to 4 and 0 to 5, respectively).

Table 2.

Tobacco use transitions among all women using cigarettes at T1 (n = 3,767 weighted % =26.8, 95% CI =25.7, 27.9)—Population Assessment of Tobacco and Health (PATH) Study, United States, 2013–2016

Overall Proportion of Women Exhibiting Each Transition				
	Time 2 Tobacco Use			
Time 1 Tobacco Use	**Longitudinal Transition**	**Weighted %**	**95% CI**	**Weighted N**
Any cigarette use (26.8%, 95% CI 25.7, 27.9)	Harm Maintenance	83.0	81.4, 84.6	13,471,561
	Harm Reduction	2.3	1.7, 2.9	371,545
	Harm Elimination	14.7	13.3, 16.1	2,387,178
Transitions Between Specific Tobacco Use Patterns Over Time				
	Time 2 Tobacco Use			
Time 1 Tobacco Use	**Longitudinal Transition**	**Weighted %**	95% CI	**Weighted N**
Cigarette only (65.9%, 95% CI 64.2, 67.6)	Harm Maintenance	82.8	80.7, 84.8	8,848,404
	Harm Reduction	1.9	1.2, 2.5	200,788
	Harm Elimination	15.4	13.5, 17.3	1,643,628
Cigarette, ENDS (16.8%, 95% CI 15.4, 18.1)	Harm Maintenance	87.3	83.7, 90.8	2,374,711
	Harm Reduction	4.1	1.9, 6.2	110,340
	Harm Elimination	8.6	5.9, 11.4	235,248
Cigarette, other tobacco, ENDS (11.7%, 95% CI 10.4, 13.0)	Harm Maintenance	84.4	79.7, 89.1	773,952
	Harm Reduction	3.3	0.8, 5.8	30,468
	Harm Elimination	12.3	7.9, 16.7	112,633
Cigarette, other tobacco (5.7%, 95%CI 4.8, 6.5)	Harm Maintenance	77.7	73.0, 82.2	1,474,495
	Harm Reduction	1.6	0.5, 2.7	29,949
	Harm Elimination	20.8	16.3, 25.3	395,669

Table 3.

Multinomial logistic regressions examining predictors of harm reduction (left) and harm elimination (middle) transitions compared to maintaining use of combusted tobacco products (harm maintenance)[a] among females age 18–49 yrs using cigarette-like products at Time 1 of the Population Assessment of Tobacco and Health (PATH) Study, United States, 2013–2016

	Harm Reduction[a]			Harm Elimination[a]					
	AOR	95% CI		*AOR*	95% CI		*F*	df	*p*
T1 ENDS Use							20.44	2	<0.0001
Yes	**1.92**	**1.04**	**3.55**	**0.56**	**0.42**	**0.76**			
No	Reference			Reference					
Age							49.59	4	<0.0001
18–24 yrs	**2.38**	**1.32**	**4.30**	**2.61**	**1.82**	**3.75**			
25–34 yrs	1.26	0.63	2.52	1.18	0.82	1.69			
35–49 yrs	Reference			Reference					
Education							63.75	6	<0.0001
< High School/GED	Reference			Reference					
High School Graduate	1.29	0.57	2.90	**1.93**	**1.23**	**3.02**			
Some college/Associates	1.86	0.85	4.10	**2.54**	**1.76**	**3.68**			
Bachelor's/Advanced degree	0.81	0.24	2.70	**4.67**	**3.04**	**7.16**			
Race[b]							30.14	6	<0.0001
Non-Hispanic White	Reference			Reference					
Non-Hispanic Black	0.59	0.21	1.64	**1.69**	**1.22**	**2.34**			
Hispanic	0.97	0.46	2.06	**2.45**	**1.67**	**3.61**			
Other	0.70	0.26	1.86	1.31	0.67	2.56			
Poverty[c]							6.58	2	0.04
Below poverty level	Reference			Reference					
At or above poverty level	**1.92**	**1.07**	**3.47**	1.22	0.95	1.58			
Presence of Youth in the Home							0.40	2	0.82
Yes	0.90	0.48	1.70	0.94	0.74	1.18			
No	Reference								
U.S. Census Region							8.37	6	0.21
Northeast	0.69	0.25	1.91	0.73	0.46	1.15			
Midwest	0.66	0.28	1.56	0.63	0.42	0.95			
South	0.86	0.41	1.83	0.67	0.47	0.95			
West	Reference			Reference					
Substance Use									
Past Year Alcohol Use[d]							1.79	2	0.41
Yes	1.02	0.46	2.23	0.82	0.60	1.11			

	Harm Reduction[a]			Harm Elimination[a]					
	AOR	95% CI		*AOR*	95% CI		*F*	df	*p*
No	Reference			Reference					
Past Year Illicit Drug Use[e]							3.17	2	0.21
Yes	0.66	0.36	1.20	0.80	0.59	1.10			
No	Reference			Reference					
Psychiatric Status[f]									
Externalizing	1.14	0.86	1.49	**1.18**	**1.04**	**1.34**	8.28	2	0.02
Internalizing	1.03	0.83	1.27	**0.88**	**0.79**	**0.97**	7.04	2	0.03
Pregnancy							71.52	2	<0.0001
Yes	0.38	0.06	2.50	**5.97**	**3.92**	**9.10**			
No	Reference			Reference					
T1 Other Combusted Product Use							1.18	2	0.55
Yes	0.74	0.40	1.36	0.91	0.65	1.27			
No	Reference			Reference					

Notes.

[a]Reference category for regressions is a harm-maintaining transition (continuing to use cigarettes and/or other combusted tobacco products in W2/W3).

[b]The four racial/ethnicity categories (White, Black, Other, Hispanic) are mutually exclusive; persons identifying as Hispanic are categorized as such, regardless of race, "Other" includes non-Hispanic persons of two or more races and persons belonging to racial groups other than non-Hispanic White or non-Hispanic Black.

[c]Based on reported family income and poverty thresholds published by the U.S. Department of Health and Human Services.

[d]Self-reported alcohol use within the past year.

[e]Self-reported use of at least one of the following illicit drugs within the past year: marijuana, cocaine or crack, prescription drugs such as painkillers or sedatives used without a prescription, stimulants like methamphetamine or speed, or any other drugs such as heroin, inhalants, solvents, or hallucinogens.

[f]Represents the average number of symptoms experienced in the past year reflecting a possible internalizing or externalizing psychiatric disorder (score ranges 0 to 4 and 0 to 5, respectively).