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Original Investigation

Associations Between Nicotine Knowledge and Smoking Cessation Behaviors Among US Adults Who Smoke

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Abstract

Introduction: Misperceptions about nicotine's contribution to smoking-related health harms could complicate efforts to reduce the public health burden of smoking. Study goals were to describe nicotine knowledge among adults who smoke and investigate whether misperceiving nicotine as a source of health harm was associated with beneficial health behaviors, or lower uptake of using less harmful sources of nicotine to support smoking cessation attempts.

Method: This study used longitudinal data from 9140 adults who participated in four waves of the Population Assessment of Tobacco and Health Study and were current smokers during the first wave. Logistic regressions estimated odds ratios for correct responses across six aspects of nicotine knowledge assessed in Wave 4. Longitudinal models estimated associations between misperceptions and cigarette consumption, and odds of making a quit attempt; self-reported cessation; e-cigarette use; and use of NRT or e-cigarettes to support quit attempts.

Results: Participants who were non-White, older, and had lower educational attainment or income tended to be least knowledgeable about nicotine. Misperceiving nicotine as harmful to health was associated with increased odds of quit attempts (AOR: 1.12, 95% CI: 1.03, 1.23), lower odds of cessation success (AOR: 0.84, 95% CI: 0.73, 0.98) and e-cigarette use (AOR: 0.79, 95% CI: 0.72, 0.86), and lower odds of using NRT (AOR: 0.84, 95% CI: 0.71, 0.99) or e-cigarettes to support quit attempts (AOR: 0.59, 95% CI: 0.49, 0.71).

Conclusion: Harm reduction efforts may be impeded by misperceptions about nicotine. Further work should evaluate the effects of correcting such misperceptions through public education.

Implications: This study provides longitudinal evidence that among adult smokers, misperceiving nicotine as a primary cause of smoking-related diseases may be associated with reduced cessation success and lower likelihood of using less harmful nicotine products. These misperceptions may therefore impede efforts to encourage smokers ready to quit to use evidence-based cessation support such as nicotine replacement during quit attempts and limit the success of policies designed to shift smokers to less harmful sources of nicotine. Further work should evaluate the longitudinal effects of correcting nicotine misperceptions through public education targeted toward adults who smoke.

Introduction

Efforts to reduce smoking in the United States have been highly successful.[1,2] However, 14% of US adults were current smokers in 2019,[3] and 16 million adults live with smoking-related conditions such as heart disease, pulmonary and respiratory diseases, and cancers.[1] Studies have identified risk factors underlying persistently higher rates of smoking among individuals with mental health conditions, substance use disorders, socioeconomic disadvantage, and sexual and gender minorities.[1,4] These groups of adults may stand to benefit substantially from regulations intended to reduce the public health burden of smoking, including potential US Food and Drug Administration (FDA) initiatives to (1) reduce the addictive potential of cigarettes through enacting a nicotine product standard, and (2) encourage those unable or unwilling to quit smoking to switch to less harmful, noncombustible products.[5] The success of such strategies may be impeded if adults who smoke do not understand the distinction between the addictive potential of nicotine in tobacco, and the health harms of smoking conferred by other chemicals via tobacco smoke.[6,7]

Nicotine is a highly addictive tobacco constituent that does not pose zero absolute health harm[8]; however, the risks for smoking-related diseases are primarily driven by other tobacco constituents and chemicals absorbed into the body as a result of combustion.[1,9,10] Burning tobacco produces smoke composed of gas and particulates, including thousands of chemical constituents, many of which are linked to a range of smoking-related diseases.[11,12] Among current, established smokers, chemical exposure via tobacco smoke poses significantly greater risk of disease than exposure to nicotine in noncombustible forms.[9] However, misconceptions about the relative harms of tobacco products and the role of nicotine in contributing to smoking-related disease are prevalent.

Previous efforts to assess overall knowledge about nicotine and the distinction between nicotine's addictive potential and its effects on health have found that many US adults hold significant misperceptions about nicotine's contribution to smoking-related diseases. In a nationally representative study, approximately half of participants who were current smokers (n = 854) reported that nicotine contributed to increased health risks and cancers caused by smoking.[13] Greater misperceptions were also linked to increased support for a reduced-nicotine product standard, though such a policy would make cigarettes less addictive rather than less harmful to health. Another nationally representative study among smokers and non-smokers (including never and former smokers, n = 3738)

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found similar results: almost three quarters of participants either were "not sure" about this relationship or incorrectly endorsed nicotine as a contributor to smoking-related cancers; many of these participants also erroneously believed that reducing nicotine in cigarettes would make them less harmful.[14] Misperceptions about nicotine's contribution to cancer were most prevalent in that study among non-White, older, and less educated participants. Such beliefs have the potential to complicate efforts to reduce health harm among smokers: if reducing nicotine in cigarettes is believed to make them less harmful, smokers may have less motivation to quit if a nicotine product standard is enacted, and young smokers may have fewer concerns about initiating smoking if they perceive reduced-nicotine content cigarettes as safer.[15]

Evidence suggests that misperceptions about non-cigarette nicotine sources are common and could impede efforts to encourage smokers to transition to lower harm sources of nicotine, either to support cessation efforts, or to replace cigarette smoking. Among studies focused on nicotine knowledge and comparative risk perceptions, investigators have found that perceptions that nicotine was a major contributor to health harms were common,[14,16–19] and that inaccurate nicotine health harm perceptions were associated with inaccurate relative (compared to cigarettes) health risk perceptions for e-cigarette among youth,[18] for nicotine replacement therapy (NRT) and snus relative health risk perceptions among daily smokers,[17] and for e-cigarettes and NRT among adult current and ex-smokers.[19] Misperceptions about the relative harm of e-cigarettes compared to combustible cigarettes may in fact be worsening over time: in an investigation using two nationally representative, longitudinal surveys, the proportion of adults who perceived e-cigarettes to be as harmful as cigarettes rose significantly, from 11.5% in 2012 to 36.4% in 2017.[20] These misperceptions are likely to have increased even more as a result of a 2019 outbreak of vaping-related lung injuries.[21] Taken together, these findings suggest that misperceptions about nicotine's role in smoking-related health harms may negatively impact relative risk knowledge, and could impede harm reduction efforts for adults who smoke.

While evidence suggests that misperceptions about nicotine and its relative risks delivered across products may be common among adults,[13–15,20] and may reduce engagement with lower harm products,[15,22] there is a lack of evidence about the longitudinal associations between nicotine knowledge and tobacco use behaviors among smokers, such as quit attempts, successful cessation, and engagement with potentially less harmful sources of nicotine. Previous representative studies have relied primarily on cross-sectional data and included a limited range of questions about nicotine's potential for health harm versus addiction. The current study leverages nationally representative longitudinal data from a large cohort of adult smokers who participated in four waves of data collection for the Population Assessment of Tobacco and Health (PATH) study to (1) provide recent, generalizable estimates characterizing the current state of knowledge about nicotine's addictive potential and contribution to health harm among a large sample of smokers, (2) investigate whether misperceptions about nicotine's role in health harms were positively or negatively associated with variation in behaviors such as cigarette consumption, quit attempts, self-reported cessation, and use of lower harm products (e-cigarettes) at future waves, and (3) investigate whether misperceiving nicotine as harmful to health was associated with lower probability of using a range of cessation supports such as NRT, e-cigarettes, or counseling during recent quit attempts.

Method

Participant Sample

Study data were obtained from 9140 adults (ages 18+) who reported past 30-day cigarette smoking in Wave 1 of the PATH Study (2013–2014) and who participated in all four publicly available waves of data (2013–2018).[23] The PATH Study is a longitudinal cohort study consisting of approximately 45 000 youth and adults sampled to be representative of the civilian noninstitutionalized US population based on a multistage area probability design.[24] Further details regarding the design and methods for the PATH study are available in Hyland et al.[25] The weighted response rate among adults eligible to participate in all four waves was 74%.[24]

Measures

Nicotine Knowledge

Knowledge about nicotine was assessed based on responses to six statements about nicotine, four of which concerned its potential health effects and two of which focus on its addictive potential. Two statements (one from each category; #3 and #5 below) were presented to participants in all four waves of data collection and are included in this study's longitudinal models as independent predictors (see *Statistical Analysis*, below). The four additional statements were also presented in Wave 4, offering recent information on six aspects of nicotine knowledge, each included as binary, independent predictors for Wave 4 cross-sectional models.

Harm

1. How harmful do you think nicotine is to health? (5-point scale from not at all to extremely).
2. How harmful do you think the nicotine in cigarettes is to health? (5-item scale from not at all to extremely).
3. Do you believe nicotine is the chemical that causes most of the cancer caused by smoking cigarettes? (4-item scale from definitely not to definitely yes).
4. In your opinion, do you think that cigarettes with lower amounts of nicotine are less harmful to a person's health than regular cigarettes? (less harmful, about the same, more harmful).

Addictiveness

5. Do you believe nicotine is the main substance in tobacco that makes people want to use tobacco products? (4-item scale from definitely not to definitely yes).
6. In your opinion, do you think that cigarettes with lower amounts of nicotine are less addictive, about the same, or more addictive than regular cigarettes? (less addictive, about the same, more addictive).

Based on accepted knowledge about nicotine's potential for health harm versus addiction among adults,[1] investigators for this study assigned binary indicators representing correct (1) versus incorrect (0) responses. See Supplementary Table 1 for full response options and coding summary.

Table 1. Weighted Descriptive Characteristics of the Study Sample at Wave 4 Data Collection (n = 9140)

	Total sample$n$ = 9140N[1]=41 933 272 % (CI)
Sociodemographic characteristics	
Male	54.1% (0.65)
Age	
18–24	6.6% (0.24)
25–34	26.0% (0.60)
35–44	20.0% (0.58)
45–54	19.5% (0.48)
55–64	18.2% (0.53)
65+	9.7% (0.44)
Race/ethnicity	
Non-Hispanic White	66.7% (0.68)
Non-Hispanic Black	13.8 (0.41)
Hispanic	13.6 (0.46)
Other	5.9 (0.30)
Educational attainment	
HS/GED equiv. or less	54.3% (0.73)
Some college/associates	31.9% (0.68)
Bachelors+	13.8% (0.48)
Annual HH income	
Less than $10k	19.4% (0.63)
$10k–24 999	26.1% (0.59)
$25k–49 999	24.5% (0.64)
$50k–99 999	20.8% (0.61)
$100k+	9.2% (0.45)
Tobacco use characteristics	
Currently report smoking	80.7% (0.52)
Cigarettes per day (CPD, past 30 days) (M ± SE)	6.79 (0.12)
Number of days smoking (past 30 days) (M ± SE)	19.9 (0.20)
Dependence score (M ± SE)	2.74 (0.01)
Past 30-day E-cigarette use	15.8% (0.43)
Past 30-day other tobacco use	20.2% (0.46)

[1]N refers to the size of the US noninstitutionalized population to which the study sample generalizes.

Tobacco Use Behaviors

Participants were queried in each wave about cigarette consumption, attempts to quit smoking, and self-reported cessation success, as well as past 30-day use of a potentially less harmful product (e-cigarettes). A measure of total past 30-day cigarette consumption was constructed by multiplying average cigarettes per day (CPD) by the number of days smoking cigarettes; the continuous measure was log-transformed for analyses.[26] Binary indicators were assigned for a quit attempt since previous data collection, self-reporting successful cessation, and past 30-day e-cigarette use. A second set of analyses focused on participants who made a quit attempt (successful or unsuccessful) during any period. They were assigned binary indicators representing whether they had used evidence-based cessation interventions such as counseling and non-prescription medicinal NRT such as gum, lozenges, inhalers, or patches, and whether they had used e-cigarettes to support cessation efforts.

We did not perform separate analyses among adults who were not interested in quitting, as this study was intended to provide generalizable information about associations between knowledge and behavior among most smokers, and results from our sample (90.3% at Wave 1) and other studies[27] suggest that the vast majority of smokers report a desire to quit, whether they make attempts or quit successfully.

Additional Population Characteristics

Cross-sectional models also assessed significant associations between nicotine knowledge and a broad range of population characteristics associated with variation in tobacco use.[1,4,27]

Sociodemographic Characteristics

Gender (male/female), age (6 categories from age 18 to 65+), race and ethnicity (four categories: non-Hispanic White, non-Hispanic Black, Hispanic, other), educational attainment (three levels: high school diploma/GED equivalent or less, some college or an associate degree, bachelor's degree+), and annual household income (five levels from less than $10,000 to $100,000+).

Additional Tobacco Use Characteristics

Indicators were assigned for past 30-day use of other tobacco products (traditional cigars, cigarillos, filtered cigars, snus

pouches, smokeless, and dissolvable tobacco), and nicotine dependence. Nicotine dependence was assessed based on the average score (range: 1–5) on a 16-item composite scale of items from the Wisconsin Inventory of Smoking Dependence Motives (WISDM) and the Nicotine Dependence Syndrome Scale (NDSS), a scale adapted for use among users of a range of tobacco products.[28] The Cronbach's alpha score for scale reliability was 0.96 or greater among this study's sample during each wave of data collection, indicating excellent reliability.[29]

Mental Health, Health Care, and Access to Care Characteristics

Cross-sectional models included indicators for lifetime experience of mental health conditions including internalizing disorders, externalizing symptoms, and substance use disorders, all associated with greater likelihood of initiating and continuing smoking.[30,31] Symptoms were assessed based on three subscales from the Global Assessment of Independent Needs-Short Scale (GAIN-SS).[32] Other indicators associated with variation in general tobacco use outcomes included a proxy measure for access to care (binary indicators representing any insurance coverage versus none and having seen a medical doctor within the past 12 months) and whether a doctor had advised quitting smoking (1 = yes).

Statistical Analysis

Weighted Descriptive Statistics

Based on the broad range (six items) of nicotine perception questions only available in Wave 4, weighted descriptive statistics described the study sample during Wave 4 data collection. Cross-sectional survey weights from Wave 4 were used to provide generalizable estimates for selected study sample characteristics during the most recent survey period and adjust for potential bias due to nonresponse.[24]

Cross-Sectional Models

Weighted logistic regressions reported odd ratios associated with likelihood of agreement with each nicotine statement, adjusted for sociodemographic, tobacco use, and mental health and health care/access characteristics. Adjusted odds ratios (AORs) from these regressions were used to create a heatmap (Figure 1) representing significant associations ($p < .05$) between indicating a correct response to each question, and the relative magnitude of each significant association. Selected estimates are presented in Figure 1; all coefficients are presented in the Supplementary material, as is a heat map key.

Longitudinal Models

Participant data were used to estimate longitudinal linear and logistic regression models representing associations between

	Harm Topics (green = more accurate) AOR (SE)				Addiction Topics (green= more accurate) AOR (SE)	
Sociodemographic Characteristics	1. Nicotine is harmful to health.	2. Nicotine in cigarettes is harmful to health.	3. Nicotine is the main chemical in cigarettes that causes cancer.	4. Lower nicotine cigarettes vary in harm to health compared to regular cigarettes.	5. Nicotine is the main substance that makes people want to use tobacco products.	6. Lower nicotine cigarettes would be less addictive than regular cigarettes.
Sex						
Female	Ref	Ref	Ref	Ref	Ref	Ref
Male	0.62** (0.05)	0.62** (0.05)	0.89 (0.06)	1.09 (0.09)	1.11 (0.11)	1.11 (0.10)
Age						
18-24	Ref	Ref	Ref	Ref	Ref	Ref
25-34	1.07 (0.17)	1.34 (0.34)	1.22 (0.16)	0.81 (0.13)	1.03 (0.14)	0.60** (0.08)
35-44	1.07 (0.14)	1.26 (0.26)	1.51* (0.19)	0.83 (0.15)	0.78 (0.12)	0.41** (0.07)
45-54	1.10 (0.19)	1.34 (0.34)	2.08** (0.27)	1.37 (0.24)	1.03 (0.15)	0.55* (0.10)
55-64	0.97 (0.14)	1.32 (0.15)	2.60** (0.40)	1.73* (0.28)	1.45 (0.25)	0.65 (0.11)
65+	0.85 (0.13)	1.15 (0.16)	2.32** (0.35)	1.66 (0.34)	1.91* (0.37)	0.62 (0.11)
Race/Ethnicity						
Non-Hispanic White	Ref	Ref	Ref	Ref	Ref	Ref
Non-Hispanic Black	1.44* (0.15)	1.34* (0.13)	2.46** (0.25)	1.15 (0.13)	1.27 (0.14)	0.89 (0.12)
Hispanic	1.80** (0.22)	1.77** (0.21)	2.17** (0.32)	1.20 (0.17)	1.39 (0.24)	0.81 (0.12)
Other	1.34 (0.20)	1.38 (0.19)	1.58 (0.25)	1.78* (0.32)	1.15 (0.24)	1.28 (0.25)
Education						
HS/GED Equiv. or less	Ref	Ref	Ref	Ref	Ref	Ref
Some college/Assoc.	0.88 (0.06)	0.82* (0.06)	0.61** (0.05)	1.08 (0.10)	0.91 (0.09)	1.30 (0.10)
Bachelors+	0.94 (0.10)	0.83 (0.09)	0.50** (0.05)	1.88** (0.23)	0.92 (0.13)	1.84** (0.24)
Annual HH Income						
Less than $10k	Ref	Ref	Ref	Ref	Ref	Ref
10k-24,999	0.96 (0.10)	0.89 (0.08)	0.86 (0.08)	0.76 (0.09)	1.14 (0.15)	1.06 (0.14)
25k-49,999	0.85 (0.09)	0.74 (0.07)	0.95 (0.12)	0.62** (0.08)	1.23 (0.16)	0.96 (0.14)
50k-99,999	0.86 (0.09)	0.79 (0.07)	0.75 (0.09)	0.57** (0.08)	1.17 (0.16)	1.02 (0.19)
100k+	0.68* (0.09)	0.65** (0.08)	0.56** (0.09)	0.58* (0.10)	1.73 (0.33)	1.47 (0.26)

[1]Coefficient estimates result from weighted, cross-sectional models with heteroskedasticity-robust standard errors.
Notes: Color-coded cells with bolded estimates indicate statistically significant coefficients at p<0.05.; *indicates statistical significance p<0.01, ** indicates statistical significance<0.001

Figure 1. Weighted associations between nicotine knowledge and selected sociodemographic characteristics among wave 4 participants (n = 9140).

(within-individual) changes in agreement with each of the two nicotine statements available for all four waves of data collection, and changes in tobacco use outcomes (level of cigarette consumption and odds of making a quit attempt, self-reporting successful cessation, past 30-day use of e-cigarettes, and using cessation supports for quit attempts).

Longitudinal models employed heteroskedasticity robust standard errors as well as a person-level random effect, due to low within-individual variation in agreement with each nicotine statement over time, and to take advantage of both within- and between-individual variation to provide adjusted estimates for both time varying characteristics and selected, time-invariant population characteristics of high priority to public health officials (see Sociodemographic characteristics, above).[27,33] The threshold for determining statistical significance was set a priori at .05, and all analyses were conducted using Stata 16 (College Station, TX).

Results

Weighted, Selected Characteristics of Sample Participants During Wave 4

Adults in the study sample were predominantly male (54%), between the ages of 25 and 54 (65%), reported race and ethnicity as non-Hispanic White (67%), earned a high school degree or GED equivalent or less (54%), and reported annual household income less than $50 000 (60%) (Table 1). While 100% of the participants were past 30-day smokers at Wave 1 data collection, 80.7% still reported past 30-day smoking at Wave 4.

Weighted Proportions of Participant Agreement with Statements About Nicotine at Wave 4 Data Collection

Incorrect responses to a question about nicotine's harmfulness to health were reported by 68.9% of participants (SE: 0.56); 64.6% incorrectly reported that nicotine in cigarettes was very/extremely or not at all harmful to health (SE: 0.53), and 63.3% thought that nicotine was probably or definitely the main contributor to smoking-related cancers (SE: 0.63). Conversely, only 12.5% (SE: 0.41) agreed that reducing nicotine in cigarettes would make them less harmful. In terms of nicotine's addictive properties, 82.9% (SE: 0.44) of participants agreed that nicotine was responsible for driving continued cigarette use, however only 13.1% (SE: 0.46) agreed that reducing nicotine would make cigarettes less addictive.

Weighted, Adjusted Associations Between Nicotine Knowledge at Wave 4 Data Collection and Population Characteristics

Figure 1 illustrates associations between nicotine knowledge and sociodemographic characteristics. Men had higher adjusted odds than women of answering correctly versus incorrectly to questions about nicotine's potential health harms (AORs: 0.62 (both questions); 95% CI: 0.53, 0.73; $p < .001$), and adults with the highest level of household income had higher odds of correctly versus incorrectly answering questions related to both health harm (AORs: 0.65–0.68; 95% CI: 0.52, 0.87; $p < .001$) and nicotine's contribution to smoking-related cancers (AOR: 0.56; 95% CI: 0.41, 0.76; $p < .001$) than adults with the lowest income level (Figure 1). Adults with the highest educational attainment were more likely to correctly report that reducing nicotine content would make cigarettes less addictive (AOR: 1.84; 95% CI: 1.43, 2.67; $p < .001$), and adults at the highest level of annual income were more likely to correctly respond to both addiction statements. In contrast, adults older than the 18–24 reference group were significantly more likely to agree with statements that nicotine is a main contributor to cancers (AORs: 1.51–2.32; 95% CI: 1.17, 3.13; $p < .01$) and that lowering nicotine would make cigarettes less harmful. Non-Hispanic Black and Hispanic adults had greater odds of reporting that nicotine was harmful to health ($p < .01$), and all non-White and Hispanic participants had greater odds of reporting that nicotine was a contributor to cancers.

Significant inconsistencies across knowledge aspects were noted within subpopulations. Adults older than the 18–24 reference group were more likely to agree with the statement that nicotine drives tobacco use, while being less likely to agree that lowering nicotine would make cigarettes less addictive. Those with higher educational attainment also exhibited inconsistent views about nicotine and health harm: these groups had greater odds of correctly disagreeing with the statement that nicotine in cigarettes causes cancer, but greater odds of incorrectly agreeing that reducing nicotine would make cigarettes less harmful.

Longitudinal Associations Between Nicotine Knowledge and Tobacco Use Behaviors

Longitudinal analyses revealed no significant association across waves between level of cigarette consumption and nicotine knowledge across waves (Table 2). However, misperceiving nicotine to be a cause of cancers was associated with increased odds of making a smoking quit attempt versus no attempt compared

Table 2. Longitudinal Associations Between Nicotine Knowledge and Tobacco Use Behaviors (n = 9140)

	Log of total cigarettes[1,3] n = 8575		Quit attempt[2,3] n = 8250		Quit smoking[2,3] N = 8333		Past 30-day E-cigarette use[2,3] N = 8618	
	ß (95% CI)	*p*-value	AOR (95% CI)	*p*-value	AOR (95% CI)	*p*-value	AOR (95% CI)	*p*-value
Nicotine drives cigarette use	−0.02 (−0.06, 0.03)	.48	0.92 (0.84, 1.02)	.13	0.97 (0.82, 1.15)	.76	1.03(0.92, 1.14)	.64
Nicotine causes cancer	−0.02 (−0.06, 0.02)	.33	**1.12** (1.03, 1.23)	.01	**0.84** (0.73, 0.98)	.02	**0.79**(0.72, 0.86)	<.01
CPD	–		**0.98** (0.97, 0.99)	<.01	**0.72** (0.68, 0.77)	<.01	**0.99**(0.99, 1.00)	.01
Nicotine Dependence	**0.59** (0.57, 0.62)	<.01	**1.07** (1.03, 1.12)	<.01	**0.43** (0.37, 0.49)	<.01	**1.14**(1.09,1.20)	<.01

Notes: Bolded values indicate $p < .05$.
[1]Coefficient estimates result from a longitudinal, linear regression model with a person-level random effect and heteroskedasticity robust standard errors.
[2]Adjusted odds ratios result from a longitudinal, logistic regression model with a person-level random effect and heteroskedasticity robust standard errors.
[3]Models were adjusted for CPD (except for model 1: log of total cigarettes), nicotine dependence, sex, age, race/ethnicity, educational attainment, annual household income, past 12-month visit to a healthcare practitioner, and wave. See Supplementary material for full set of coefficient estimates.

to those with correct perceptions about nicotine's role in causing cancer (AOR: 1.12; 95% CI: 1.03, 1.23; $p = .01$), reduced odds of reporting successful cessation (AOR: 0.84; 95% CI: 0.73, 0.98; $p = .02$), and lower odds of reporting current e-cigarette use versus no use (AOR: 0.79; 95% CI: 0.72, 0.86; $p < .01$).

Longitudinal Associations Between Nicotine Knowledge and Use of Cessation Supports During Quit Attempts

Among sample participants who made a quit attempt during the study period ($n = 4688$), misperceiving nicotine to be a main cause of smoking-related cancers was associated with lower odds of reporting NRT (AOR: 0.84; 95% CI: 0.71, 0.99; $p = .04$) or e-cigarette use (AOR: 0.59; 95% CI: 0.49, 0.71; $p < .01$)to support quit attempts, but no significant difference was observed for the odds of reporting use of counseling (Table 3).

Discussion

The goal of this study was to assess whether variation in nicotine knowledge, and specifically misperceptions that nicotine is a source of health harms, predicted variation in the odds of engaging in health promoting behaviors (making attempts to quit and achieving self-reported cessation) and using lower harm, noncombustible nicotine-containing products among adults who smoke combustible cigarettes. We found that adults who smoke were likely to hold inconsistent views about nicotine and overestimate its potential for health harm, that misperceiving nicotine as a cause of smoking-related diseases was associated with increased odds of making a quit attempt but lower likelihood of achieving self-reported cessation or engaging with e-cigarettes, and that misperceiving nicotine as a cause of smoking-related diseases was associated with lower probability of using nicotine replacement and e-cigarettes during quit attempts.

Our finding that many adults who smoke hold misperceptions about the role of nicotine in smoking-related health harm is consistent with findings from previous cross-sectional studies among a range of populations.[13,14,34–37] A unique contribution of the current study is the addition in the PATH Wave 4 questionnaire of questions allowing us to provide representative, generalizable estimates assessing inconsistencies in perceptions about nicotine, yielding information that adults who smoke hold inconsistent views. We found that a majority thought nicotine was accountable for smoking-related diseases but held the correct, but inconsistent view that reducing nicotine in cigarettes would not make them less harmful. Similarly, while most participants were likely to agree that nicotine drives cigarette use, a very small proportion agreed that reducing nicotine would make cigarettes less addictive. The extent to which these inconsistencies are due in part to the cognitive difficulty of understanding the distinction between absolute and relative harm, or underlying perceptions about harms or addictive qualities of cigarettes beyond those cited by participants is unknown and requires further investigation. This highlights the difficulties inherent in designing effective public education interventions to reduce combustible product use among adults, particularly in light of extensive public health messaging designed to deter youth from tobacco use. The combined influence of effective anti-smoking, anti-e-cigarette use, and nicotine education campaigns may have contributed to confusion about the relative risks of nicotine delivered across different products, and to deep-seated perceptions about the harms of cigarettes such that participants are unlikely to perceive reduced-nicotine cigarettes to be safer or less addictive.[20,38–41] We observed a significant time trend supporting this hypothesis, where participants were less likely to report past 30-day e-cigarette use over time, and those attempting to quit were less likely to report using NRT or e-cigarettes to support their efforts.

Key findings from longitudinal models suggested that misperceptions about nicotine-attributable health harm may, in fact, motivate a desirable behavioral outcome among smokers (quit attempts), but this potential benefit did not translate to increased odds of successfully achieving cessation, and of using an effective, evidence-based support tool such as nicotine replacement therapy. Participants attributing significant health harms to nicotine were also less likely to report past 30-day e-cigarette use during the study period, or e-cigarette use to support cessation efforts. While evidence regarding the effectiveness of e-cigarette use as a cessation support tool is mixed,[42] e-cigarettes represent significantly less relative health risk to smokers than combustible products,[9] and misperceptions about nicotine could impede switching to these products among adults who smoke. Nicotine education interventions varying in design attributes have been developed and tested among subpopulations of adult participants, and exposure to educational messaging about nicotine has been found across these studies to be effective in increasing nicotine knowledge,[43–47] decreasing false beliefs about lower harm nicotine products,[34] and increasing intentions to seek further information about e-cigarettes.[37] However, multiple studies

Table 3. Longitudinal Associations Between Nicotine Knowledge and Strategies to Support Past 12-Month Quit Attempts

	Used NRT[1,2] $n = 4345$		Used counseling[1,2] $n = 4316$		Used E-cigarettes[1,2] $n = 4316$	
	AOR (95% CI)	*p*-value	AOR (95% CI)	*p*-value	AOR (95% CI)	*p*-value
Nicotine drives cigarette use	1.03 0.85, 1.25	.77	0.79 (0.60, 1.03)	.08	1.11(0.89, 1.40)	.36
Nicotine causes cancer	**0.84** (0.71, 0.99)	.04	1.15 (0.91, 1.46)	.24	**0.59** (0.49, 0.71)	<.01
CPD	1.01 (1.00, 1.01)	.27	1.01 (1.00, 1.02)	.05	0.99 (0.98, 1.01)	.34
Nicotine Dependence	**1.60** (1.48, 1.73)	<.01	**1.49** (1.34, 1.66)	<.01	**1.31**(1.19, 1.43)	<.01

Notes: Bolded values indicate $p < .05$.
[1]Adjusted odds ratios result from a longitudinal, logistic regression model with a person-level random effect and heteroskedasticity robust standard errors.
[2]Models were adjusted for CPD, nicotine dependence, sex, age, race/ethnicity, educational attainment, annual household income, past 12-month visit to a healthcare practitioner, and wave. See Supplementary material for full set of coefficient estimates.

have observed no significant effect of exposure to nicotine educational messaging on behavioral intentions to switch products,[34,37] and most have focused on education about nicotine rather than comparative product risk, suggesting further should evaluate the effects of comparative risk education on behavioral intentions and trajectories of observed tobacco use behaviors.

Our findings also revealed patterns of greater nicotine misperceptions and lower likelihood of cessation success, use of a lower harm product, and use of nicotine substitutes during quit attempts across population characteristics. Congruent with previous findings,[14,36] older adults, participants who were non-White, and those with lower levels of income or education tended to be more likely to hold misperceptions about nicotine. These population characteristics were also generally associated with lower rates of quitting, cessation success, and e-cigarette use in this study (see Supplementary material) and in previous investigations.[48–51] These findings highlight the potential for misperceptions of nicotine harm to exacerbate tobacco-related health disparities.[1,4,27] Further work should investigate population-specific perceptions about nicotine and relative risks of its delivery across different products, to inform targeted public health education, and inform policymakers about the likely impact of different regulatory alternatives.

Limitations of this study included the self-report nature of the cessation outcome, the inability to control for unobservable characteristics that may influence tobacco use behavior due to employing random rather than fixed-effects models and use of list-wise deletion in cross-sectional and longitudinal models. A missing data analysis revealed, however, limited opportunities for missing data across main outcomes and key predictors to present potential bias, based on high rates of complete data for nicotine questions (>95% per wave). However, our analysis revealed that misperceptions of nicotine causing cancer were associated with increased odds of missing responses to questions about quit attempts and successful cessation, a potential source of bias that may render our estimates for those outcomes to be conservative, particularly since our models also revealed that those missing quit attempt data were more likely to have reported successful cessation rather than being less likely to quit. Strengths included the comprehensive nature of nicotine knowledge questions asked of Wave 4 participants in the PATH Study, longitudinal data from a large, nationally representative cohort of adults who smoked cigarettes in Wave 1, and ability to control in models for a wide range of known factors influencing tobacco use behaviors.

Conclusion

This study provided evidence that nicotine misperceptions are common among US adults who smoke and that misperceiving nicotine as harmful to health is associated with quit attempts among smokers, but also associated with reduced cessation success, lower likelihood of using a less harmful product, and reduced use of evidence-based nicotine replacement therapy to support cessation attempts. Based on evidence from this study and others, evaluating the long-term effects of correcting these misperceptions via public education is a necessary step toward reducing the public health burden of smoking.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at https://academic.oup.com/ntr.

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Declaration of Interests

The authors have no conflicts nor competing interests to declare.

Data Availability Statement

The data underlying this article are available in the National Addiction & HIV Data Archive Program, at https://doi.org/10.3886/ICPSR36498.v11. The datasets were derived from sources in the public domain: United States Department of Health and Human Services. National Institutes of Health. National Institute on Drug Abuse, and United States Department of Health and Human Services. Food and Drug Administration. Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] Public-Use Files. Inter-university Consortium for Political and Social Research [distributor], 2020-10-21. https://doi.org/10.3886/ICPSR36498.v11

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