



Short Communication

“Tobacco-free nicotine” electronic cigarette perceptions and use among adolescents and adults in five New England states

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ABSTRACT

Introduction: More brands are using tobacco-free nicotine (TFN) in electronic cigarettes (e-cigarettes) and these products are becoming increasingly popular. The term TFN and claims about its properties can mislead consumers about the harms and addictiveness of TFN e-cigarettes, which may increase initiation of these products among non-smokers or influence current smokers' decisions to adopt TFN e-cigarettes as a harm reduction measure.

Methods: We conducted an observational, cross-sectional survey of 777 adolesc aged 13–17 and 655 current adult cigarette smokers residing in Massachusetts, Connecticut, New Hampshire, Rhode Island, or Vermont about their TFN e-cigarette awareness, use, perceptions, and susceptibility. We examined the association between prior awareness of TFN and use, perceptions, and susceptibility.

Results: One-third of adolescents and adults reported being aware of TFN. TFN e-cigarette use was less common than tobacco-derived nicotine (TDN) e-cigarette use among adolescents (8.9 % vs. 30.5 %) and adults (21.1 % vs. 79.4 %). Compared to unaware adolescents, adolescents who were aware of TFN more frequently reported being more likely to use TFN compared to TDN e-cigarettes and that TFN e-cigarettes are more addictive than those containing TDN. Aware adult smokers more frequently reported that TFN e-cigarettes are more addictive than TDN e-cigarettes, TFN e-cigarettes cause some harm, TDN e-cigarettes cause little harm, and that TFN and TDN e-cigarettes are equally harmful than those who were unaware previously.

Conclusion: Public health education campaigns are needed to educate consumers about the harms and addictiveness of TFN e-cigarettes.

1. Introduction

Electronic cigarettes (e-cigarettes) were introduced in the United States in 2007 and have been marketed as a harm reduction tool (Dewhirst, 2021). They have become the most popular form of tobacco used by adolescents (Arrazola et al., 2015) and young adults (Kramarow & Elgaddal, 2023), but few adult cigarette smokers have switched to exclusively using e-cigarettes (Kramarow & Elgaddal, 2023). More recently, tobacco companies have begun selling e-cigarettes containing synthetically derived nicotine. This form of nicotine is marketed as “tobacco-free nicotine” (“TFN”) by e-cigarette companies and is

manufactured from petroleum-based products. Puff Bar launched its TFN e-cigarettes in February 2021 in an attempt to circumvent FDA regulations (Maloney, 2021), which Congress addressed a year later by granting FDA the authority to regulate synthetic nicotine products (Simoneau, 2022). In 2021, 26.8 % of middle and high school current e-cigarette users reported Puff Bar as their usual brand (Park-Lee et al., 2021). One year later, 44 disposable e-cigarette brands and 63 e-liquid brands were marketing their products as synthetic nicotine or TFN (Ramamurthi et al., 2022).

Claims about TFN products can mislead consumers about their harms and addictiveness. Puff Bar's website advertises TFN as “a virtually

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tasteless, odorless nicotine without the residual impurities of tobacco-derived nicotine” (Puff Bar, n.d.). Other companies are advertising TFN as a clean and pure alternative to tobacco-derived nicotine (TDN; Ramamurthi et al., 2022). Such claims may reduce harm perceptions, as advertising that claims TDN cigarettes are “additive-free” decreases harm perceptions (Baig et al., 2018). Prior research among young adults has found that 40 % misinterpret the term TFN to mean that the product contained tobacco but not nicotine, both nicotine and tobacco, or neither nicotine nor tobacco (Morean et al., 2022) and that descriptions of Puff Bar products including TFN claims increases intentions to use and decreases harm perceptions of Puff Bar products (Chen-Sankey et al., 2023).

Scientific uncertainty about the relative harm of TFN compared to TDN e-cigarettes (Cwalina et al., 2021) and frequent mislabeling of the percentage of nicotine content in TFN products (Jordt, 2021) complicates efforts to educate consumers. Nicotine, regardless of its source, is addictive, increases susceptibility to addiction to other drugs (Kandel & Kandel, 2014), and can cause structural changes in the brain that negatively affect mood, memory, and attention (Siqueira & AAP Committee on Substance Use and Prevention, 2017) as well as cardiovascular damage (Benowitz & Burbank, 2016). Correcting misperceptions about TFN is important because they threaten efforts to reduce e-cigarette use among adolescents and young adults (Cwalina et al., 2021). Misperceptions could also decrease adult smokers’ adoption of e-cigarettes as a harm reduction strategy (Adzrago et al., 2022; Perski et al., 2020; Persoskie et al., 2019). Further evidence that TFN marketing leads to misperceptions about the content, harms, or addictiveness of the products would support regulating use of the term (Morean et al., 2022). In this study, we examined how prior awareness of TFN, a proxy for exposure to TFN marketing, is associated with TFN e-cigarette use, perceptions, and susceptibility among adolescents and adult smokers residing in five New England states.

2. Materials and methods

2.1. Participants and procedures

We surveyed a convenience sample of approximately 120 adolescents aged 13–17 and 120 adult smokers each month between April 2021 and August 2022 about their tobacco product use and perceptions as part of a larger study assessing the impact of Massachusetts’ 2020 ban on flavored tobacco (Commonwealth of Massachusetts, 2023) on adolescents’ tobacco use and adult smokers’ tobacco cessation. Participants were recruited through an online consumer research panel, Prodege, that uses television, radio, and online advertisements to obtain hard-to-reach populations, including teens, young adults, and Hispanic Americans. Participants were eligible if they resided in Massachusetts, Connecticut, New Hampshire, Rhode Island, or Vermont and were proficient in English. Additionally, adults were eligible only if they had used one or more tobacco products in the past 30 days. Items assessing TFN awareness, use, and perceptions were included in the survey waves between February and August 2022. Items assessing TFN susceptibility were added in April 2022 and included in all subsequent waves. Participants could complete the survey more than once; only the participant’s earliest response to the TFN items was included in this analysis for a final analytic sample of 777 adolescents and 655 adults for awareness, use, and perception items and 470 adolescents and 299 adults for susceptibility items. The study was approved by the University of Pennsylvania Institutional Review Board.

Although not representative of New England, our sample included diverse demographic groups (participant characteristics are shown in Table S1). New England’s population was estimated to be 9.1 % Black or African American and 12.1 % Hispanic or Latino (U.S. Census Bureau, 2021a), both of which were overrepresented in our adolescent sample and underrepresented in our adult sample. Among New England adults, 8.3 % were estimated to have less than a high school education, 24.9 %

have a high school degree or equivalent, 23.7 % have some college or an associate’s degree, 24.2 % have a bachelor’s degree, and 19.0 % have an advanced degree (U.S. Census Bureau, 2021b). Those with a high school degree or some college were overrepresented in our sample.

2.2. Measures

The survey included 11 closed-ended items about perceptions and use of TFN as part of a larger survey on tobacco use. These items measured whether participants had heard of TFN previously (1 item); whether they had ever used TFN (1 item); the absolute harm of e-cigarettes containing TFN and TDN (2 items); the relative harm, addictiveness, and likelihood of using of e-cigarettes containing TFN compared to those with TDN (3 items); and susceptibility to using e-cigarettes containing TFN (4 items). Items assessing susceptibility (e.g., “Have you ever been curious about using a vape product containing tobacco-free nicotine?”) were added to the survey in April 2022 and were asked only of those who reported never using TFN e-cigarettes. Following a scoring algorithm that has been previously validated as predictive of future smoking (Pierce et al., 1996) and e-cigarette use (Bold et al., 2018; Nicksic & Barnes, 2019; Seo et al., 2020), participants were considered susceptible if they did not answer ‘Definitely not’ to all 4 items. The survey questions, response options, sources, and citations are available in Appendix A.

We assessed demographic characteristics including age, gender, sexual orientation, race, ethnicity, education, and state of residence. We also measured self-reported tobacco use, including ever use of cigarettes and e-cigarettes and number of days of tobacco (adults only), cigarette, and e-cigarette use in the past 30 days.

2.3. Analysis

Analyses were conducted using STATA v15.1. Chi-Square Tests of Independence were performed to determine whether responses varied between those who had and had not heard of TFN previously. For items where the Chi-Square Test was significant, we conducted post-hoc testing with Bonferroni correction to evaluate which response options differed between groups.

3. Results

3.1. Participant characteristics

Participant characteristics are summarized in Table S1. The average age was 44.0 years (SD = 13.6) for adults and 15.1 years (SD = 1.4) for adolescents. Among adolescents, half identified as boys (50.8 %) and most were heterosexual or straight (82.9 %), white (79.4 %), and not of Hispanic, Latino/a/x, or Spanish origin (84.6 %). Among adults, most identified as women (64.7 %) and were heterosexual or straight (86.7 %), white (89.8 %), and not of Hispanic, Latino/a/x, or Spanish origin (92.8 %).

Nearly one-third (30.5 %) of adolescents reported ever use of e-cigarettes. Of these, 70.6 % had used in the past 30 days and 9.3 % had used every day in the past 30 days. Over three-quarters (79.4 %) of adults reported ever smoking e-cigarettes. On average, adults used a tobacco product on 22.7 (SD = 10.9) days over the past 30 days.

3.2. TFN Awareness, Use, and susceptibility

Table 1 and Table 2 summarize the distribution of use, and perceptions of TFN and TDN e-cigarette harms and addictiveness among adolescents and adult smokers, respectively, stratified by their awareness of TFN products. About one-third of adolescents (31.3 %) and adults (38.2 %) had heard of TFN and 8.9 % of adolescents and 21.1 % of adults had ever used TFN e-cigarettes. Adolescents and adults who had heard of TFN previously were significantly more likely to have used a TFN e-

Table 1

TFN awareness and use and perceptions of TFN and TDN e-cigarette harms and addictiveness among New England adolescents (N = 777).

	Aware of TFN			Total	
	Yes	No/Don't Know	Total		
	N = 243	N = 534	N = 777		
Used TFN e-cigarettes previously*					
Yes, within past 30 days [†]	27 (11.11)	11 (2.06)	38 (4.89)		
Yes, but not within past 30 days [†]	20 (8.23)	11 (2.06)	31 (3.99)		
No, never used [†]	190 (78.19)	460 (86.14)	650 (83.66)		
Don't know [†]	6 (2.47)	52 (9.74)	58 (7.46)		
Likelihood of using TFN e-cigarettes compared to TDN e-cigarettes*					
Less likely	34 (13.99)	80 (14.98)	114 (14.67)		
Equally likely	84 (34.57)	148 (27.72)	232 (29.86)		
More likely	54 (22.22)	76 (14.23)	130 (16.73)		
Don't know [†]	71 (29.22)	230 (43.07)	301 (38.74)		
Harm of TFN e-cigarettes*					
No harm	16 (6.58)	17 (3.18)	33 (4.25)		
Little harm	33 (13.58)	66 (12.36)	99 (12.74)		
Some harm	94 (38.68)	182 (34.08)	276 (35.52)		
A lot of harm	83 (34.16)	171 (32.02)	254 (32.69)		
Don't know [†]	17 (7.00)	98 (18.35)	115 (14.80)		
Harm of TDN e-cigarettes*					
No harm	8 (3.29)	8 (1.50)	16 (2.06)		
Little harm	27 (11.11)	33 (6.18)	60 (7.72)		
Some harm	86 (35.39)	193 (36.14)	279 (35.91)		
A lot of harm	113 (46.50)	243 (45.51)	356 (45.82)		
Don't know [†]	9 (3.70)	57 (10.67)	66 (8.49)		
Relative harm of using TFN vs. TDN e-cigarettes*					
Less harmful	59 (24.28)	93 (17.45)	152 (19.59)		
Equally harmful	142 (58.44)	286 (53.66)	428 (55.15)		
More harmful	20 (8.23)	31 (5.82)	51 (6.57)		
Don't know [†]	22 (9.05)	123 (23.08)	145 (18.69)		
Relative addictiveness of TFN vs. TDN e-cigarettes*					
Less addictive	62 (25.51)	110 (20.60)	172 (22.14)		
Equally addictive	139 (57.20)	288 (53.93)	427 (54.95)		
More addictive [†]	27 (11.11)	30 (5.62)	57 (7.34)		
Don't know [†]	15 (6.17)	106 (19.85)	121 (15.57)		
	N = 132	N = 338	N = 470		
Susceptible to using TFN^a					
Yes	57 (43.18)	145 (42.90)	202 (42.98)		
No	75 (56.82)	193 (57.10)	268 (57.02)		

*Denotes items that had a statistically significant (p < 0.05) difference between those who were aware and unaware (or did not know) of TFN previously based on Pearson's Chi-square test.

[†] Denotes responses for which there was a statistically significant difference between those who were aware and unaware (or did not know) of TFN previously based on Bonferroni-corrected post-hoc testing.

^a Susceptibility items asked only of participants who completed the survey in April 2022 or later and who reported never using TFN e-cigarettes. Participants were considered susceptible to using TFN if they did not answer 'Definitely not' to each susceptibility item (i.e., the mean of the susceptibility items was greater than 1).

cigarette within the past 30 days or prior to the past 30 days than those who had not. Aware adolescents were also significantly more likely to report that they would be more likely to use TFN compared to TDN e-cigarettes than those who were unaware. Among adolescent and adult never-users of TFN e-cigarettes, having heard of TFN previously was not significantly associated with susceptibility to using TFN e-cigarettes. Responses to individual susceptibility items are summarized in [Table S2](#).

3.3. Perceptions of TFN harms and addictiveness

Among adolescents, those who were aware of TFN e-cigarettes previously were significantly less likely to report that they did not know the absolute and relative harms of using TFN compared to TDN e-cigarettes compared to those who were unaware. Aware adolescents were more likely to report that TFN e-cigarettes were more addictive than TDN e-

Table 2

TFN awareness and use and perceptions of TFN and TDN e-cigarette harms and addictiveness among New England adults (N = 655).

	Aware of TFN			Total	
	Yes	No/Don't Know	Total		
	N = 250	N = 405	N = 655		
Used TFN e-cigarettes previously*					
Yes, within past 30 days [†]	56 (22.40)	19 (4.69)	75 (11.45)		
Yes, but not within past 30 days [†]	45 (18.00)	18 (4.44)	63 (9.62)		
No, never used [†]	138 (55.20)	329 (81.23)	467 (71.30)		
Don't know [†]	11 (4.40)	39 (9.63)	50 (7.63)		
Likelihood of using TFN e-cigarettes compared to TDN e-cigarettes*					
Less likely	54 (21.60)	88 (21.73)	142 (21.68)		
Equally likely	102 (40.80)	130 (32.10)	232 (35.42)		
More likely	45 (18.00)	57 (14.07)	102 (15.57)		
Don't know [†]	49 (19.60)	130 (32.10)	179 (27.33)		
Harm of TFN e-cigarettes*					
No harm	9 (3.60)	15 (3.70)	24 (3.66)		
Little harm	53 (21.20)	59 (14.57)	112 (17.1)		
Some harm	131 (52.40)	149 (36.79)	280 (42.75)		
A lot of harm	31 (12.40)	60 (14.81)	91 (13.89)		
Don't know [†]	26 (10.40)	122 (30.12)	148 (22.60)		
Harm of TDN e-cigarettes*					
No harm	2 (0.80)	10 (2.47)	12 (1.83)		
Little harm [†]	48 (19.20)	48 (11.85)	96 (14.66)		
Some harm	118 (47.20)	156 (38.52)	274 (41.83)		
A lot of harm	64 (25.60)	107 (26.42)	171 (26.11)		
Don't know [†]	18 (7.20)	84 (20.74)	102 (15.57)		
Relative harm of using TFN vs. TDN e-cigarettes*					
Less harmful	60 (24.00)	88 (21.73)	148 (22.60)		
Equally harmful [†]	146 (58.40)	188 (46.42)	334 (50.99)		
More harmful	16 (6.40)	21 (5.19)	37 (5.65)		
Don't know [†]	28 (11.20)	108 (26.67)	136 (20.76)		
Relative addictiveness of TFN vs. TDN e-cigarettes*					
Less addictive	50 (20.00)	73 (18.02)	123 (18.78)		
Equally addictive	159 (63.60)	225 (55.56)	384 (58.63)		
More addictive [†]	21 (8.40)	15 (3.70)	36 (5.50)		
Don't know [†]	20 (8.00)	92 (22.72)	112 (17.10)		
	N = 197	N = 299			
Susceptible to using TFN^a					
Yes	70 (68.63)	144 (73.10)	214 (71.57)		
No	32 (31.37)	53 (26.90)	85 (28.43)		

*Denotes items that had a statistically significant (p < 0.05) difference between those who were aware and unaware (or did not know) of TFN previously based on Pearson's Chi-square test.

[†] Denotes responses for which there was a statistically significant difference between those who were aware and unaware (or did not know) of TFN previously based on Bonferroni-corrected post-hoc testing.

^a Susceptibility items asked only of participants who completed the survey in April 2022 or later and who reported never using TFN e-cigarettes. Participants were considered susceptible to using TFN if they did not answer 'Definitely not' to each susceptibility item (i.e., the mean of the susceptibility items was greater than 1).

cigarettes, and unaware adolescents were more likely to report that they did not know the relative addictiveness of TFN compared to TDN e-cigarettes.

Compared to adult participants who were unaware of TFN, a significantly greater proportion of those who were aware reported that TFN e-cigarettes were somewhat harmful, TDN e-cigarettes had little harm, and that TFN and TDN e-cigarettes were equally harmful. They were also more likely to report that TFN e-cigarettes are more addictive than TDN e-cigarettes. Unaware adults were significantly more likely to report "don't know" to all harm and addictiveness items.

4. Discussion

Our survey is the first to assess awareness, use, and perceptions of

TFN e-cigarettes among adolescents and older adult smokers. About one-third of adolescents and adult smokers were aware of TFN. Adolescents and adults who were unaware of TFN previously were significantly more likely to report that they did not know their likelihood of using TFN compared to TDN e-cigarettes and the harms and addictiveness of these products. As awareness of TFN increases through use and marketing of these products, it is possible that those who were previously unaware adopt perceptions more similar to those who were aware previously.

Adolescents who had heard of TFN previously had greater likelihood of using TFN e-cigarettes and perceived them to be more addictive than TDN e-cigarettes. Future research should investigate how these perceptions affect e-cigarette initiation, sustained use, and product selection. Although we could not estimate population prevalence, the high prevalence of TFN susceptibility among adolescents in our study calls for further research on the prevalence of susceptibility among this population because curiosity about TFN e-cigarettes has been found to be associated with more favorable perceptions of these products, including lower perceptions of harm and addictiveness (Camenga et al., 2022).

Among adults, awareness of TFN was associated with significantly increased likelihood of reporting that TFN e-cigarettes have some harm, TDN e-cigarettes have little harm, that TFN and TDN e-cigarettes are equally harmful, and that TFN e-cigarettes are more addictive. Research is needed to examine whether these perceptions of TFN encourage or discourage current smokers from switching to e-cigarettes exclusively.

Public health campaigns could be deployed to educate consumers about the potential harms and addictiveness of TFN e-cigarettes, to inoculate consumers against claims about TFN made by e-cigarette sellers, and to correct misperceptions about the relative harm and addictiveness of TFN e-cigarettes. FDA regulation to eliminate the use of the term “tobacco-free nicotine” in marketing and on product packaging might also decrease initiation of this highly addictive product category.

4.1. Limitations

The generalizability of our findings is limited as our survey used a convenience sample of adolescents and adults in five New England states. Another limitation is that we did not present an exhaustive list of all e-cigarette products containing TFN. It is possible that e-cigarette users are unknowingly using TFN products and thus the proportion of users is underestimated.

Author contributions

AT, KE, JW, DG and MG contributed to conceptualizing the study and obtaining study funding. BZ contributed to conceptualizing the study and led the data analysis. All authors contributed to the interpretation of the analysis, writing, and approved the final manuscript. AT is responsible for the overall content as guarantor.

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CRedit authorship contribution statement

Brittany A. Zulkiewicz: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Jonathan P. Winickoff:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Mark A. Gottlieb:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Karen M. Emmons:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Andy S.L. Tan:** Conceptualization,

Methodology, Funding acquisition, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: JW has served as an expert witness in litigation against the tobacco industry. MG has represented clients in litigation against the tobacco industry.

Data availability

Data will be made available on request.

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.abrep.2024.100524>.

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