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A Naturalistic, Randomized Pilot Trial of E-Cigarettes: Uptake, Exposure, and Behavioral Effects

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Abstract

Background—Most studies of electronic nicotine delivery systems (ENDS) compare self-selected users vs. non-users. The few randomized studies to date generally support a positive impact on reducing smoking behavior, but these studies are focused on guided ENDS use. This study presents a randomized naturalistic trial of ENDS with prospective outcomes of uptake and behavioral changes in smoking.

Methods—Adult smokers with minimal ENDS history were randomized in a 2:1 ratio to receive product for 3 weeks (n=46), or not (n=22). Changes in nicotine delivery (16mg vs. 24mg), midway through the study allowed a compelling opportunity to examine two ENDS products compared to control group. Primary outcomes, assessed via daily diaries during sampling period and in-person lab visits over 4 months, included uptake and usage of ENDS, cessation-related outcomes, and exposure to smoke constituents.

Results—All ENDS participants tried product at least once, with 48% of 24mg and 30% of 16mg using their assigned product for the entire sampling period. Within 24mg ENDs group, 57% made an independent purchase of ENDS, vs. 28% of 16mg, and 14% of control participants (p=.01). Smokers in both ENDS groups significantly reduced their smoking, whereas control participants did not (p=.03). Cessation behaviors (quit attempts, biologically verified abstinence) numerically but not statistically favored ENDS participants.

Conclusions—Results suggest that cigarette smokers are willing to use ENDS with trends towards reduced cigarette smoking and positive changes in cessation-related behaviors.

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Impact—Randomized naturalistic trials such as presented herein are needed to understand the population impact of e-cigarettes.

Keywords

E-cigarettes; ENDS; Randomized clinical trial; Smoking cessation; Regulatory science

Introduction

The proliferation of electronic nicotine delivery systems (ENDS, or e-cigarettes) has generated a rapidly growing yet divergent literature on how these products impact smoking behavior (1,2). Most studies that assess the impact of ENDS on smoking are either cross-sectional or observational cohort designs (3,4). Evidence suggests that the majority of ENDS users have intention to reduce and/or quit smoking (5), and a range of studies have shown ENDS use to be associated with quit attempts (6), reduction and/or cessation (7-16). More recent cohort studies further document a positive association between use and subsequent quitting (17,18), particularly when ENDS are used regularly (19-21). However, not all studies have been consistent, and some have shown negative associations with quitting (22-25). The rapidly evolving marketplace combined with methodological constraints across studies likely contributes to inconsistent findings, making it difficult to draw firm conclusions about the value of ENDS as a smoking cessation method. A major barrier to study interpretation, especially from observational studies, is the reliance on self-selected samples of users vs. non-users. This self-selection bias presents challenges when determining causal inferences with regard to ENDS and their impact on smoking behavior.

A more direct test of the impact of ENDS comes through randomized controlled trials. Only four such trials exist (26-29) and two are pending (30,31). All but one of the existing RCTs were based on early-generation products. The first was a study of Italian smokers (27) randomized smokers (N=300) to high, moderate, or placebo ENDS. Rates of abstinence after 3 months (11%, 17%, 4% in each group respectively) and 12 months (13%, 9%, 4%) suggested higher quit rates among active ENDS groups. The second study, a non-inferiority, cessation-focused trial (N=657), came from New Zealand (28,32). Smokers were randomized to receive 1) an early generation ENDS product, 2) transdermal patch, or 3) placebo ENDS. Abstinence rates numerically but not statistically favored the ENDS product over both the nicotine patch and placebo. The third study was a small scale (N=48), randomized trial from Belgium that showed short term (2-month) increases in quitting as a function of newer generation ENDS which dissipated over longer term (8 months) follow-up (26). Finally, a recent reduction-focused trial demonstrated significant decreases in smoking as compared among active vs. placebo ENDS (29).

Most of the above trials focused on prescribed and/or structured e-cigarette use, i.e., to reduce and/or quit smoking, which is entirely different from real-world uptake. Naturalistic provision of ENDS, yet still within a randomized design, allows for assessment of self-determined use and its causal impact on downstream smoking behavior while avoiding biases of self-selection inherent in the observational studies. We have previously used the naturalistic randomized clinical trial framework to evaluate uptake, patterns and

consequences of nicotine products, both snus (33) and NRT (34,35), and now extend this design to ENDS.

The current study presents results from a pilot (N=68) test of short-term (3 weeks) ENDS sampling vs. not, with follow-up for an additional three months (clinicaltrials.gov identifier: NCT02357173). Our general aim was to approximate the real-world scenario in which smokers are exposed to e-cigarette and decide on their own if and how they will use them. Our specific focus was on: 1) uptake and usage of the ENDS product during the sampling period and beyond, 2) smoker evaluation of the product, 3) changes in smoking and cessation-related outcomes, and 4) differences in exposure to cigarette smoke constituents (i.e., cotinine, carbon monoxide, and NNAL).

Materials and Methods

Participants

Non-treatment seeking smokers were recruited from the local community (southeastern US urban area; approximately 30% non-white) using various media outlets. To be eligible, participants were required to be/have: a) age 18+, b) current smoker of ≥5 cigarettes per day for ≥1 year, c) no recent history of cardiovascular distress (heart attack in past 3 months; arrhythmia, uncontrolled hypertension), d) neither pregnant nor breastfeeding (verified), e) absence of any major current psychiatric impairment, f) current, active use of email, g) at least some concern for health effects of smoking (>none at all on a Likert scale), and h) not used any ENDS product in the past six months, and i) never purchased an ENDS product. The latter two criteria were meant to ensure a study sample that was relatively naïve to ENDS so we could more accurately gauge how the provision of the product in this study impacted use of the product and smoking behaviors.

Participants eligible during phone screen were assessed and ultimately consented during the initial in-person lab visit. Randomization to group was stratified by motivation to quit in the next 30 days (0-6 vs. 7-10 on a VAS scale) but proportioned 2:1 (ENDS:control) to increase precision estimates for e-cigarette uptake and usage. The study consisted of two phases. An initial 3-week sampling period allowed participants to use ENDS (or not), complete ecological momentary assessment (EMA; 3× daily) throughout, and visit the lab at Weeks 2, 3 and 4. At week 4, daily EMA discontinued and no further product was offered. The 3-month follow-up period consisted of lab visits at Weeks 8, 12, and 16. Study flow is depicted in Figure 1.

Participants were compensated up to $346, inclusive of EMA-contingent reimbursement. Control participants, not offered ENDS, were offered an additional $30 to compensate for the free product given to the ENDS group. All procedures were approved by our local IRB in accordance with recognized ethical guidelines. Written informed consent was obtained from all participants. Data collection began in November 2014 and continued through final follow-up in May 2016.

ENDS

Recent evidence suggests that newer generation products based on tank systems are better substitutes for cigarettes, as opposed to standard cartridge or ciga-like design products (21). However, at the time of study design, tank systems were just emerging on the market. We also believed that new converts to ENDS would likely start out with a standard cartridge design product instead of a tank system, particularly in the U.S. where cartridge systems are widely available and advertised in convenience stores. We thus chose BluCig to use in our study which at the time of study onset was the most popular product on the market (36). Also, our earlier work that showed consumer preference for BluCig among other ciga-like devices (37).

We offered ENDS group participants the choice of either traditional tobacco or menthol flavor (other flavors available but not offered to minimize methodological variance) Blu Starter Pack, with 16mg/mL nicotine (the highest dose available at study initiation). Midway through the study, the manufacturer of Blu altered the product and discontinued availability of the device, replaced with BluPlus+, with 24mg/mL nicotine, again offered in both tobacco and menthol flavorings, and with improved battery duration (4watt battery for both devices). In all, 25 participants (54%) received the Blu Starter Pack (16mg), and 21 participants (46%) received BluPlus+ (24mg); no switches were made within participants. The change in product (IRB approved) allowed us the unexpected opportunity to assess what impact, if any, the change in product design had on study outcomes. Note that the manufacturer, style of device, and packaging did not change, nor did our messaging to participants. The only difference was the strength of product. Thus trial outcomes are reported across three groups: control vs. 16mg vs. 24mg ENDS.

We selected a 3-week sampling period for three reasons. First, we believed that smokers who adopt a new product are likely to have a period of acclimation, in which they determine a) if they like it, and b) how to use it to manage cravings. Second, we wanted a sufficiently long time period to capture the ‘bookends’ of this acclimation period, inclusive of initial trial and established use. Third, this period allowed sufficient time to observe naturalistic changes in cigarette smoking. Participants were given up to seven cartridges at each of three weekly visits (BL, visits 2 & 3) during the sampling period. We purposefully over-supplied product because we did not want to artificially suppress substitution. ENDS group participants were allowed to retain any unused product after the sampling period.

Instructions on usage were kept minimal to preserve naturalistic intent. We simply suggested that ENDS could be used “*as you wish, to cut down or quit smoking, help manage smoking restrictions, or both. It is entirely up to you if and how you use this product*.” We provided participants with materials from manufacturer marketing, including messaging of a) no ashes, b) odorless, c) no after smell, and d) made in the U.S.

Assessments are structured across the four major outcomes noted above

Uptake and usage of ENDS—We adapted ecological momentary assessment (EMA) methods from prior literature (38). Through our secure, encrypted, online database (REDCap), we pre-programmed and auto-sent an email (or text message reminders to check

email) on designated diary days (all 21 days of sampling period). Participants opened a link within the email which took the user to a brief (2-5 minutes) survey, directly entered into REDCap. Participants were 'pinged' 3× daily, at semi-random intervals. Validation checks were embedded within each session to protect against rote responding (e.g., "enter 4 here"); sessions with invalid data (2%) were removed from analyses. Within each EMA session, participants were asked about products used in the past hour (electronic, conventional, both or none). If both products were used, the participant was asked to reference the most recent. Setting and context were asked for each conventional/electronic cigarette episode. We used the final EMA entry of each day to assess both a) number of e-cigarette puffing episodes and b) number of cigarettes smoked that day. Both measures thus reflect partial days, which we deemed more feasible than asking number of puffing episodes during a prior day (there is yet no established method for EMA assessment of ENDS). Participants were compensated for compliance (up to $6 per day for 21 days + $10 bonus for ≥80% EMA compliance). Overall compliance was modest but no different across groups: 58% of all EMA sessions completed.

Visit-based assessments, extending beyond the sampling period, included timeline follow-back (TLFB) methods (39) to assess both number of cigarettes smoked each day over the preceding 7 days, and whether ENDS were used (yes/no) each day over the same period. Cigarettes per day (CPD) represents an average over this 7-day period.

Product evaluation—Product evaluation was based on the Modified Cigarette Evaluation Scale (40), asked in reference to both conventional and ENDS. The mCEQ is a 12-item scale, recently adapted for ENDS (41) with five factors: a) enjoyment, b) craving reduction, c) satisfaction, d) reward, and e) aversion.

Changes in smoking and Cessation-related behaviors—Changes in smoking (CPD) are based on TLFB methods noted above. Cessation-related behaviors included the incidence of quit attempts (both any and those lasting ≥24hrs), floating abstinence (any 7-day period of self-reported non-smoking, ever in study) and point prevalent abstinence (7-day non-smoking at 4 month follow-up), the latter verified via carbon monoxide breathalyzer (<6 ppm). Motivation to quit (MTQ) in the next month was assessed through 0-10 VAS used previously (42).

Biomarkers of exposure—These included urinary cotinine, carbon monoxide, and NNAL. The latter was not included as a measure of toxicant exposure per se (as results would be specific to chosen product) but rather as a measure (like CO) to discriminate between conventional vs. e-cigarette exposure. Urine cotinine was assessed via enzyme immunoassay (DRI Cotinine Assay - Thermo-Fisher Scientific), for which the limits of quantification were 34ng/mL, and the inter-assay coefficient of variation for two controls were 3.6% and 3.0%. Urine total NNAL was measured in a separate lab (MLG) using UPLC-MS/MS as described previously (43), for which the limits of quantification were 5 pg/ml. Given skewed distribution of NNAL values, these data were first log-transformed prior to analyses.

Analyses

Demographic and smoking history data at baseline were compared between the three groups via ANOVA models and Chi-squared tests, as appropriate. Analyses of e-cigarette usage, including EMA data, were largely descriptive. Changes in biomarkers, CPD, and MTQ were all assessed via generalized estimating equations (GEE), testing group and time main effects and group × time interactions. These analyses were primarily focused on the entire 16 week study period. Whenever main or interaction effects were found, the outcomes were examined separately for both the sampling (first 4 visits) and the follow-up periods (Weeks 8-16). Assessment of cessation-related behaviors (quit attempts, abstinence) followed an intent-to-treat approach, in which all missing cases were assumed as having no quit attempts/abstinence. These cessation-related behavior outcomes were compared between the three groups via Chi-squared tests.

Results

Sample Characteristics

Table 1 provides comparisons of selected demographic and smoking history data. There were few differences between groups at baseline. We did not include covariates in any following analyses due to the pilot scope of our purpose. Participants were primarily female, Caucasian (though with representative recruitment of African Americans), moderately dependent, and with moderate motivation to quit smoking.

Uptake and Patterns of ENDS Use

All but two ENDS participants attended at least one follow-up visit, and we restrict uptake data to these individuals alone (not assuming use/no use among those missing). Of these 44, all used the e-cigarette at least once (Figure 2). Most participants reported a high frequency of use (based on TLFB), during the sampling period (>5 days per week), which decreased to about 3 days per week during follow-up. Over the 21-day sampling period, average duration of e-cigarette use was 15.4 days (SD=7.0) among 16mg ENDS participants and 17.0 (SD=5.6) among 24mg ENDS participants. Just under half (48%) of 24mg ENDS participants used product all 21 days of the sampling period, vs. 30% of 16mg ENDS participants. Collapsing across both ENDS groups, the only predictors of increased duration of use were greater income (p=.02) and nicotine dependence (p=.04). Few control participants (<5%) used an e-cigarette during the sampling period, though 19% reported ENDS use during follow-up (Figure 2; frequency of use not shown given n=4). In the week preceding the final study visit (week 16); 60% (24mg), 32% (16mg), and 13% (Control) of participants were using e-cigarettes.

Participants who received the 24mg product were significantly more likely to report independent purchase of an ENDS product compared to those who received 16mg product and those in the control group (57% vs. 28% vs. 14%; p<0.05). There were no differences in purchasing between 16mg and Control participants. There was a significant time × group interaction for intention to use e-cigarette in future, overall (p<.0001), both within the sampling period (p<.0001) and throughout follow-up (p=.02), such that ENDS participants (both 24mg and 16mg) increased in intention during the sampling period (combined M=5.5;

SD=3.1 at baseline vs. M=7.0; SD=3.1 at visit 4) while control participants decreased (M=5.4; SD=3.3 at baseline vs. M=2.7; SD=3.7 at visit 4); See Supplemental Figure 1.

Beyond TLFB assessment at each lab visit, within-week EMA data provided a more detailed account of cigarette and e-cigarette use during the sampling period. Per day cigarettes smoked (based on final EMA entry each day; not a complete day) dropped immediately upon onset of sampling period, and averaged 5.3 CPD (SD=1.1) for 24mg ENDS, vs. 8.4 CPD (SD=0.8) for 16mg ENDS, vs. 11.2 (SD=0.8) for Control participants (See Supplemental Figure 2). Number of puffing episodes per day was generally higher early in the sampling period among 24mg ENDS participants (interaction $p<.05$; See Supplemental Figure 3). Contextual correlates of smoking vs. vaping, again based on EMA data and collapsed across all groups, show that use of both conventional and ENDS was most common when smoking was allowed (90% of cigarette smoking episodes and 83% of e-cigarette episodes) and when alone (73% of cigarette smoking episodes and 69% of e-cigarette episodes). When the participant was smoking a conventional cigarette with others present, these others were most likely also smoking conventional cigarettes (66% vs. 6% vaping vs. 28% not using anything). When others were present during e-cigarette episodes, these others were less commonly but still predominantly conventional smokers (59% vs. 29% vaping, vs. 12% not using anything). Over 40% of all cigarette episodes were indoors vs. 58% outdoors, in contrast to e-cigarette episodes (65% indoor vs. 35% outdoor). Alcohol co-use was slightly higher during cigarette vs. e-cigarette episodes (6% vs. 3%). The most common settings for cigarette smoking were home (60% of all episodes), car (18%) or another home (9%). The most common settings for vaping were home (51% of all episodes), public area (16%) or at work (12%).

Product Evaluation

Product evaluation was asked for both conventional and ENDS. Three analyses were conducted, all based on the mCEQ and its adapted version for e-cigarettes: 1) control vs. ENDS (collapsed across both 16mg and 24mg ENDS) for comparison of conventional cigarettes; 2) conventional cigarettes vs. e-cigarettes, within 16mg ENDS group; and 3) same, within 24mg ENDS group. There were no differences in any of these measures at baseline, and thus no baseline adjustment was included when focused on outcomes at Visit 4, at the end of the sampling period. Results are shown in Figure 3 for all five mCEQ subscales. Though not powered for tests of equivalence, products were generally rated similarly, for all three comparisons. The only exception was a significant difference within 16mg ENDS participants, who rated their conventional cigarettes as offering higher craving relief than ENDS.

Changes in Smoking and Cessation-Related Behaviors

Consistent with EMA results, there was a significant time × group interaction for changes in cigarette smoking (CPD; averaged over the preceding 7 days prior to each lab visit), such that ENDS participants (both 16mg and 24mg) decreased their smoking, whereas Control participants did not (Supplemental Figure 4). These results also show that smoking decreases during the sampling period persisted across the follow-up period. Cigarette consumption decreased 45.1% for 24mg ENDS participants during the sampling weeks, vs.

30.2% reduction for 16mg ENDS participants, vs. an increase of 0.7% for Control participants. At the end of the sampling period, 35% (24mg ENDS), 30% (16mg ENDS), and 5% (Control) of participants had reduced their smoking by at least 50% since baseline (overall p=.07). At the end of the entire study, respective rates of ≥50% reduction were 47% vs. 16% vs. 19% (overall p=.09). There was an overall significant interaction for motivation to quit (p=.05), such that ENDS participants (both 16mg and 24mg) increased in motivation to quit during the sampling period whereas Control participants did not; though they did have comparable motivation to quit at end of study.

Cessation-related behaviors (quit attempts, floating and point prevalence abstinence) are depicted in Figure 4. There were no statistically significant group comparisons across any of these outcomes, but there were clear trends for higher rates of all outcomes among 24mg ENDS participants vs. control participants, particularly for incidence rates for 24hr quit attempts (48% vs. 23%; OR = 3.1; 95% CI: 0.8 – 11.5), and for floating abstinence (24% vs. 5%; OR = 6.7; 95% CI: 0.7 – 61.9).

Biomarkers of Exposure

There were no group × time differences for urinary cotinine, carbon monoxide, or NNAL (Supplementary Figure 5). While these interactions were not statistically evident, some differences were compelling. There was a 25% reduction in expired CO within the 24mg ENDS group by the end of the sampling period (vs. 10% in 16mg ENDS and 3% in Control). By the end of the study, reductions in CO were still evident: 29% vs. 14% vs. 12% decrease since baseline visit.

Adverse Events

During the course of the study, 11 24mg ENDS participants (52%) reported a total of 21 adverse events, compared with 9 16mg ENDS participants (36%) who reported 17 adverse events, and compared with 8 control participants (36%) who reported a total of 29 events. Collapsed across both ENDS groups, the most common side effects reported were cough (32%), nausea (24%) and mouth/throat irritation (16%), and in the control group, headache (24%), cough (21%) and mouth/throat irritation (17%). None of the adverse events resulted in study termination, or, amongst ENDS participants, early discontinuation of sampling.

Discussion

The current study presents a randomized yet naturalistic study of ENDS, with a focus on uptake and impact of ENDS over a 4-month period. An additional, unexpected strength of this study is the ability to compare (non-randomized comparison) older vs. newer e-cigarette devices, both first generation devices but with exclusive differences on strength of nicotine delivery. Thus our study affords a unique opportunity to examine two devices that vary only in nicotine strength (all other features constant) as compared to not sampling anything.

Uptake of ENDS was high, and higher among those who received newer/stronger product. All ENDS participants (both groups) used the e-cigarette given to them. Even after the conclusion of the 3-week sampling period, and through to the final study visit at 4 months, well over half of participants who were given a newer product were still using ENDS and

vaping about half of each week. While it is possible that participants held over product on hand from the sampling period, it is more telling that these same participants were significantly more likely to purchase their own product. Unfortunately, we are unable to determine if they purchased the same, similar, or more advanced ENDS. This interest in further use of product is corroborated by their stated intentions on future use, which increased over time, vs. control participants whose interest in ENDS waned. Participants generally rated cigarettes and ENDS similarly. These results are likely product-specific, but they stand in contrast to prior studies, similarly powered, showing favorability of cigarettes over e-cigarettes (44).

The context of smoking vs. vaping were largely similar. Use episodes were generally bound to places or occasions where smoking was permitted and the individual was alone. In the presence of others, conventional smoking by that other person was most common, both for cigarette smoking episodes and vaping episodes. The only contextual difference of note, not surprising, was that vaping was largely indoors whereas conventional smoking was largely outdoors. Future studies should also include assessment of nonuse contexts which would allow for comparisons to establish which situational factors determine use.

Changes in smoking behavior generally followed the same patterns as above with regard to uptake. ENDS sampling, regardless of older vs. newer/stronger product, decreased cigarette smoking, whether measured via daily fluctuations during the sampling period or more robust measures (7-day weekly averages) over time and throughout the study. More than twice as many participants receiving 24mg product (compared to control and 16mg product recipients) reduced their smoking by 50% or more by the end of the trial. Across all cessation-related behaviors, outcomes were numerically but not statistically in favor of ENDS participants, particularly those receiving newer/stronger product. While our study was solely based on a 1st generation ciga-like device, these outcomes are consistent with a number of lab-based studies showing superiority of 2nd generation (i.e., stronger) devices to control craving (45-47). These behavioral outcomes were did not easily translate to changes in exposure. We had expected that CO and NNAL would roughly correspond to changes in smoking. This was partially supported in that there was a greater decrease in CO among participants who received the newer product. There were no changes in cotinine over time, nor between groups (or their interaction), consistent with the notion that smokers self-titrate their nicotine when using ENDS (48).

Our study provided ENDS free of charge, which we recognize is not truly naturalistic. Our intent was to remove cost and access barriers which would allow a more direct test of ENDS per se. Thus we observed uptake and outcomes under conditions that were favorable to ENDS, and whether these same results would transfer to conditions when smokers have to pay for product is unclear. Forthcoming regulation of ENDS under the US FDA will prohibit product sampling. While this study does not provide sufficient data to overturn that ruling, our results are inconsistent with the interpretation that sampling does harm, at least to smokers (sampling directed to non-smokers being a much greater public health concern).

Among our study limitations, the small sample size stands out as prominent. This was not a sufficiently powered trial, and most results were not statistically significant. Our intent was

to highlight descriptive outcomes of uptake and general effect sizes for between group comparisons, all of which should guide a larger study. Second, we used a 1st generation, ciga-like product which at the time of study development was the best option available, presumed to be a "starter" product among new converts. We have no reason to believe that outcomes would be worse for a 2nd or 3rd generation e-cigarette. In fact there is reason to suggest that outcomes would be even stronger (vs. control conditions) for newer and more powerful ENDS devices, if only because they are generally more efficient in nicotine delivery, offer improved battery duration, and wider flavor assortment (45,47), all of which presumably increase consumer appeal and eventual uptake. Third, our comparison group herein was a non-sampling control, as opposed to a placebo e-cigarette condition, studied elsewhere (49). We were less interested in the nicotine-specific effects of e-cigarette uptake and more interested on the aggregate experience of trying a new product vs. not. Other, more active control groups might also be considered for future research, including: comparing ENDS sampling to provision of quit advice/materials, or perhaps samples of cessation pharmacotherapies (NRT). Finally, EMA compliance was modest, somewhat dampening our rigor to assess daily fluctuations in use. Nonetheless, almost 2500 EMA entries were recorded, mitigating this concern. The real challenges of EMA with respect to studies of ENDS pertain to quantification of use (e.g., operational definitions of puffs vs. puffing episodes), particularly when these metrics do not easily translate from conventional smoking (cigarettes per day). The current study provides some guidance worth consideration, as do others (50,51), and newer devices with built-in technology to capture these metrics significantly expand the research potential.

Our study design is worth further comment, particularly given our prior research employing similar methodology to examine sampling of other products. Randomized yet naturalistic designs allow for causal inferences on downstream behavior as well the more immediate effects of uptake and patterns of use. Prior trials have shown modest improvements in cessation-related outcomes when smokers sample NRT (34,35,52) but mixed or somewhat negative outcomes for snus (33). The relative response to multiple products can only come from studies that offer each, but these studies are rare (53,54) and difficult if focused on long-term behavioral outcomes.

In sum, the results of this small pilot study suggest strong interest and uptake of ENDS among smokers, with favorable perception comparable to that of conventional cigarettes, and trends towards positive changes in cessation-related behavior. These findings, in need of replication within a larger trial, are generally consistent with reviews elsewhere that document positive effects of ENDS among adult smokers (2,4,55). More studies are needed to rigorously examine the naturalistic impact of ENDS on smoking behavior (56).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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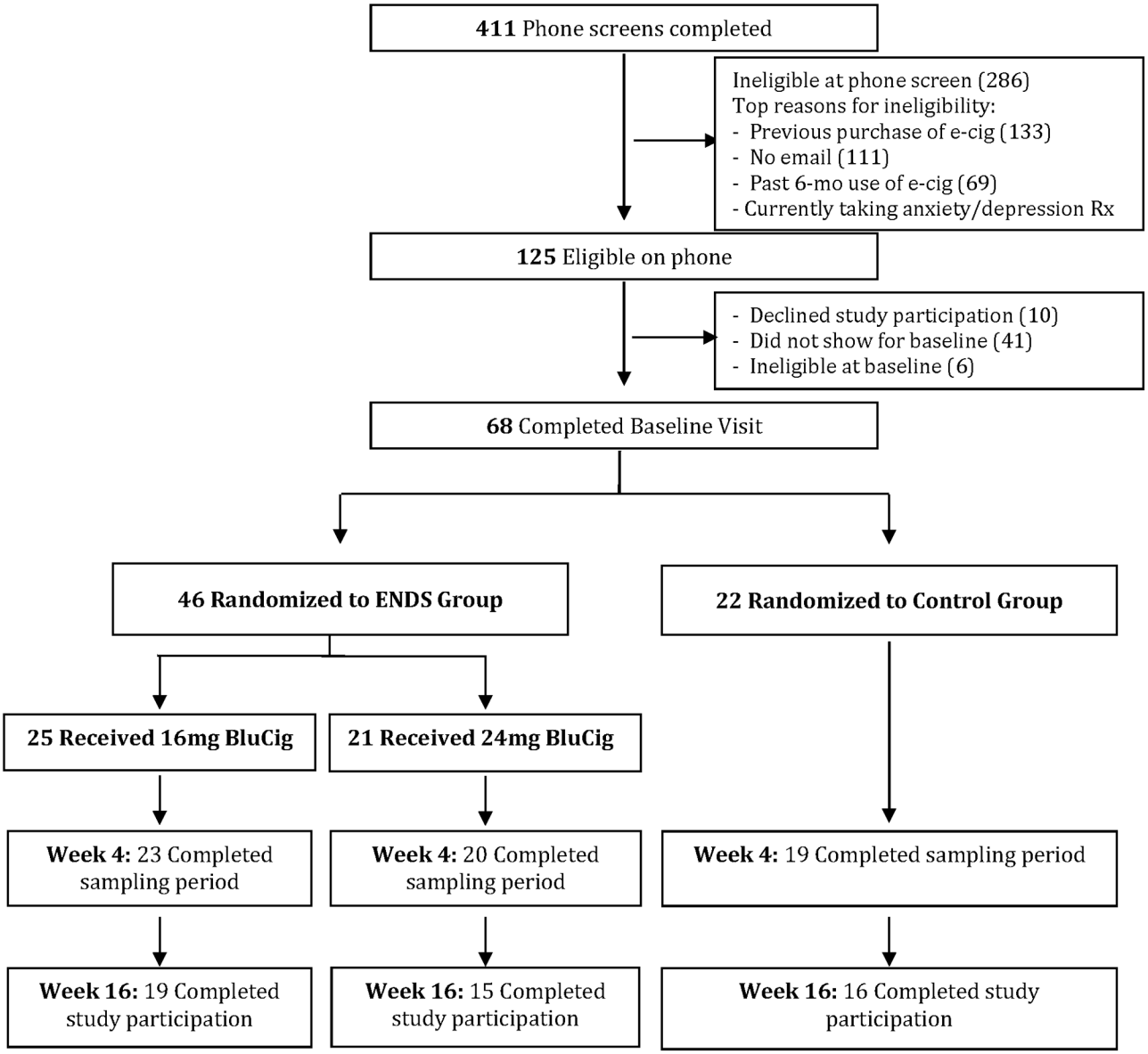


Figure 1. Participant Flow and Study Retention Rates

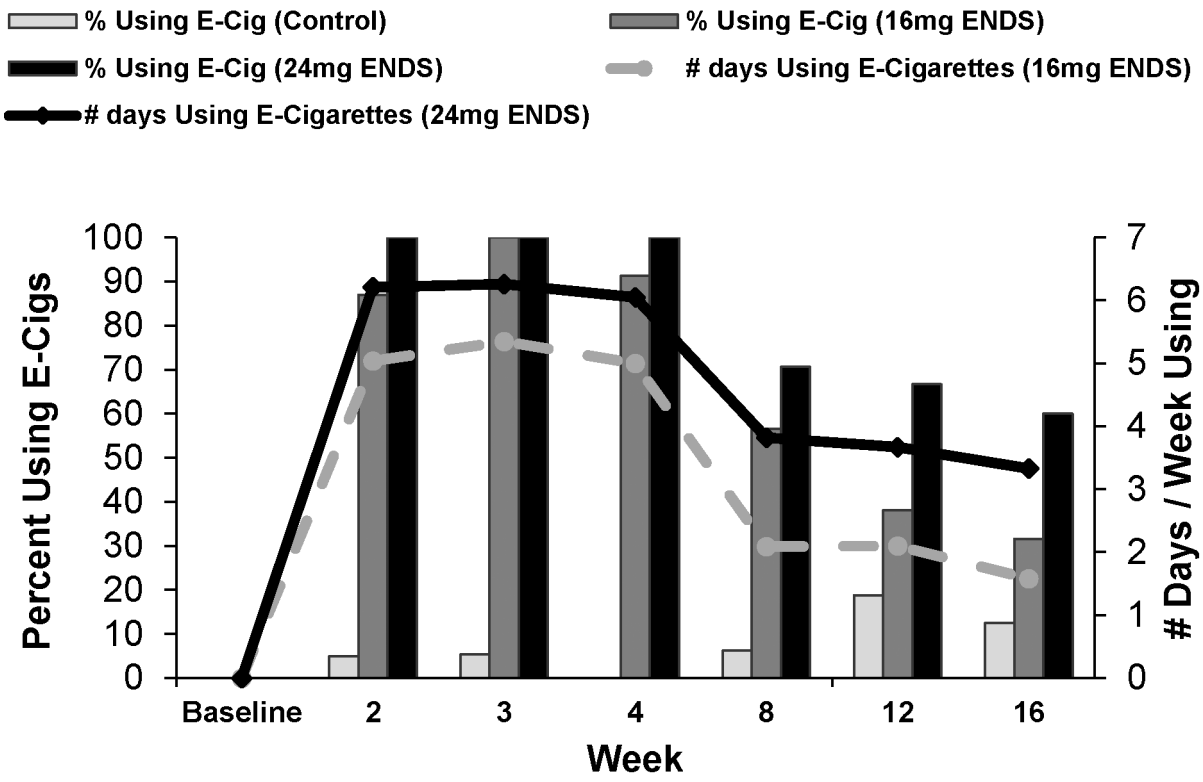
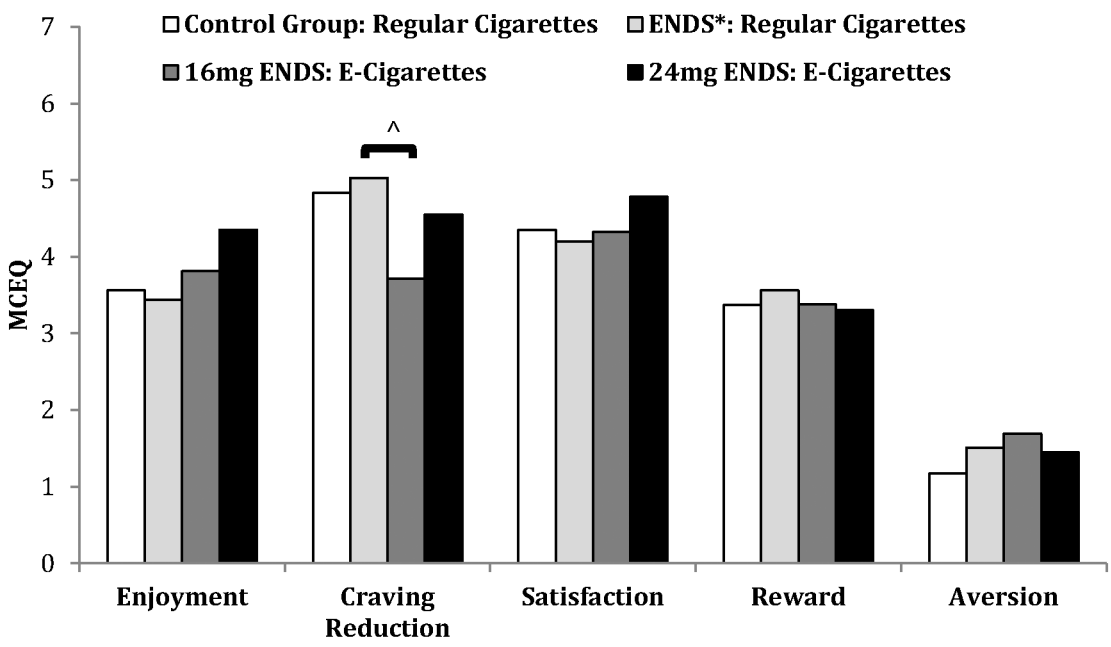


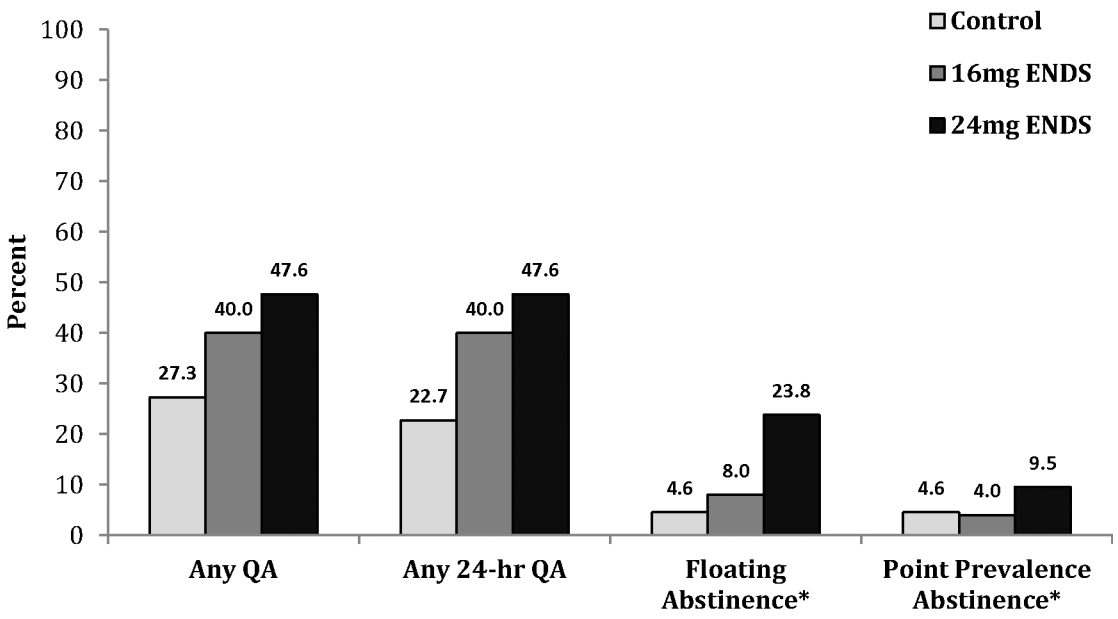
Figure 2. Incidence and Intensity of E-Cigarette Use During and Beyond Sampling Period



* Collapsed across 16mg and 24mg ENDS groups

^ p <.05

Figure 3. Product Evaluation of Both Cigarettes and ENDS at Visit 4 after Completion of ENDS Sampling)



QA = Quit Attempt
*7-day, No Smoking, either floating (ever in study) or point prevalence at 4 months. Point prevalence abstinence at 4 month follow-up was CO verified; Floating abstinence is self-report.

Figure 4. Rates of Quit Attempts and Cessation through Four Months

Table 1
Sample Characteristics (N=68) at Baseline, by Study Arm

	Control (n=22)	16mg ENDS (n=25)	24mg ENDS (n=21)	p
Age, mean (SD)	42.3 (14.2)	43.3 (14.4)	40.9 (12.3)	0.8
% Male	36%	28%	57%	0.1
Race				0.6
% White	59%	56%	48%	
% Black or African American	41%	40%	52%	
Income				0.8
Less than $25k	55%	48%	48%	
More than $25k	36%	48%	48%	
Education				0.04
Some HS	5%	12%	5%	
HS	41%	8%	43%	
Some college	36%	56%	52%	
College or greater	18%	24%	0	
% Employed full or part time	68%	44%	52%	0.3
Age began smoking	15.8 (3.2)	18.4 (4.6)	19.0 (8.4)	0.2
% Lives with another smoker	27%	56%	33%	0.3
Cigarettes per Day	16.7 (11.3)	13.9 (4.9)	15.3 (8.3)	0.9
Heaviness of Smoking (0-6)	3.1 (1.3)	2.6 (1.3)	2.9 (1.4)	0.6
% Quit Attempt in Past Year	45%	36%	19%	0.2
Lifetime # Quit Attempts	4.0 (3.4)	5.5 (8.0)	3.0 (4.4)	0.2
Motivation to Quit Smoking in Next Month (0-10)	4.0 (3.9)	5.0 (3.8)	4.4 (3.1)	0.6
Confidence to Quit Smoking (0-10)	4.7 (3.0)	3.4 (3.0)	4.3 (3.1)	0.3
Ever used e-cigarette	9%	4%	33%	0.01
Anyone you know use an e-cigarette	55%	52%	57%	0.9
Intend to use e-cigarette in future (0-10)	5.4 (3.3)	5.6 (2.9)	5.5 (3.4)	0.9