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Intraindividual Covariation Between E-Cigarette and Combustible Cigarette Use in Korean American Emerging Adults

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Abstract

Critical gaps exist in understanding the patterns and correlates of dual use of electronic cigarettes (ECs) and combustible cigarettes (CCs), particularly in ethnic minority populations. In this study, we assessed CC and EC use in the naturalistic environment using ecological momentary assessment (EMA). We hypothesized that within-subject variation in EC use (yes/no each day) would be inversely associated with within-subject variation in number of CCs consumed and craving during that same day. We also examined gender and nicotine dependence as moderators of the EC-CC and EC-craving covariations. Korean American emerging adult (KAEA; 18–25 years old) smokers ($N = 78$) completed 7 days of EMA. Participants completed EMA surveys throughout the day, which assessed CC craving, and end-of-day surveys, which assessed EC use and the number of CCs smoked that day. Generalized linear mixed models were used to predict day-level EC use, with number of CCs smoked and craving during that same day, gender, and nicotine dependence as predictors ($n = 501$). We found that within-subject variation in CC use was not associated with same-day EC use; neither was within-subject variation in craving ($ps > .27$). Gender moderated the relationship between craving and EC use on a given day ($p = .03$); only for females, on the days with higher craving, the likelihood of their EC use that day was significantly heightened. This study does not suggest that EC use is linked with lower CC smoking quantity, at least at the day level and among KAEA smokers. CC craving may play a role in dual EC-CC use for KAEA female smokers.

Keywords

e-cigarette; combustible cigarette; substitution; craving; gender

Use of ECs has rapidly increased in prevalence during recent years (King, Alam, Promoff, Arrazola, & Dube, 2013; Pearson, Richardson, Niaura, Vallone, & Abrams, 2012; Regan, Promoff, Dube, & Arrazola, 2013), with a sizable portion of CC smokers concurrently using ECs (“dual users”; Lee, Hebert, Nonnemaker, & Kim, 2014). ECs are particularly popular in young adult populations (Agaku et al., 2014; Choi & Forster, 2014). Yet, critical gaps exist in understanding the patterns and correlates of dual use, particularly in ethnic minority

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populations subject to tobacco-related disparities, providing policymakers and clinicians with little data on how to address dual use (Benowitz, Blum, Braithwaite, & Castro, 2014; Copeland, 2005). KAEAs may be at a greater risk of dual use, given the increasingly popular "vaping" subculture in ethnic enclave locations, such as Korea Town in Southern California (Sussman et al., 2014). There could be important gender differences in KAEA EC use, since there are some reports that rates of smoking are higher among Korean American men than women (36.7% vs. 9.0%), although such gender differences tend to be less pronounced in younger populations (An, Cochran, Mays, & McCarthy, 2008).

Dual users anecdotally report using ECs: (a) as an alternative in settings where CC smoke is prohibited (e.g., indoors), (b) to intentionally reduce self-exposure to CC smoke, (c) to move toward cessation of CCs altogether (Dawkins, Turner, Roberts, & Soar, 2013; Etter & Bullen, 2011; Zhu et al., 2013), or (d) to use a product perceived to be healthier than CCs (Etter, 2010; Pepper & Brewer, 2014). EC use may presumably help smokers decrease the frequency of CC use, since ECs may "substitute" for CCs. In contexts that may deter CC use (e.g., around nonsmokers) or when a person is intentionally aiming to limit CC smoke exposure, EC use ("vaping") may effectively reduce motivation to smoke CCs because the pharmacologic and sensorimotor properties of ECs may provide transitory satiation (Buchhalter, Acosta, Evans, Breland, & Eissenberg, 2005; Carpenter, Wayne, & Connolly, 2007). The satiation produced by ECs could temporarily reduce the motivation to smoke a CC, thereby reducing the total number of CCs smoked that day in comparison to days in which ECs are not used and smokers must rely only on CCs for pharmacologic and sensorimotor satiation. Also, on days in which CC use is reduced, the deprivation from CCs could provoke craving—a subjective manifestation of desire to obtain satiation—which, in turn, might motivate EC use.

The extent of EC-CC substitution and craving-provoked EC use could differ across certain subpopulations. Female smokers are more sensitive to the effects of tobacco abstinence on some domains of craving (i.e., urge to smoke for negative affect relief; Leventhal, Waters, Boyd, Moolchan, Lerman, et al., 2007; Pang, Zvolensky, Schmidt, & Leventhal, 2014) and the craving-reducing effects of smoking-related sensorimotor stimulation (e.g., denicotinized cigarettes; Barrett, 2010). Also, smokers with more severe nicotine dependence experience greater craving during brief tobacco deprivation (Leventhal, Waters, Boyd, Moolchan, Heishman, et al., 2007) and may be more motivated to use ECs as a nicotine-delivery device on days with lower CC consumption in order to maintain constant blood nicotine levels (Benowitz, 2009). Thus, female and high-dependence smokers may exhibit stronger patterns of intraindividual covariation of CC use and craving to EC use.

Extant naturalistic studies on the association between CC and EC use have applied between-subjects designs often yielding inconsistent results that sometimes suggest a positive relation (i.e., individuals who use ECs smoke more CCs than smokers who do not use ECs) (Dutra & Glantz, 2014; Etter & Bullen, 2011), inverse relation (i.e., individuals who use ECs smoke less CCs; Etter & Bullen, 2011), or null relation between the two (Grana, Popova, & Ling, 2014; Pokhrel, Fagan, Little, Kawamoto, & Herzog, 2013; Vickerman, Carpenter, Altman, Nash, & Zbikowski, 2013). Between-subjects designs cannot rule out all static between-person confounds that might be associated with both ECs and CCs but are omitted or

unmeasured in a study (e.g., density of tobacco/EC retailers in the proximity to one's residence, past difficulty quitting smoking, and willingness to try products to reduce smoking). Such confounds could spuriously inflate or suppress the relationship between ECs and CCs across individuals.

In this study, KAEA daily smokers completed repeated EMAs of CC and EC use in the naturalistic environment. While the sample was recruited solely based on smoking status without consideration of EC use, more than 25% of the sample reported using ECs at least once during the 7-day assessment period. For the reasons described above, we hypothesized that within-subject variation in EC use (yes/no on a day) would be inversely associated with within-subject variation in number of CCs consumed and level of CC craving during that same day. We also examined gender and nicotine dependence as possible moderators of intraindividual covariation of CC use and craving to EC use.

Method

Participants

The current study presents secondary analyses of the data collected for a study of contextual correlates of smoking in KAEAs (Cerrada et al., 2015). Daily KAEA smokers, who smoked at least four cigarettes per day, had been smoking for at least two years, and were not currently trying to quit, were recruited through social media, study advertisement materials, and word-of-mouth. Of the 126 individuals assessed for eligibility, 15 did not meet the inclusion criteria, 24 eligible participants opted not to participate, eight dropped out prior to completion, and one participant was discontinued due to noncompliance, leaving a final sample of 78.

Procedure

During a 7-day observation period, participants responded to EMA prompts to complete surveys on their mobile phones using a platform customized for our project (ilumivu, Inc.). Five "random" EMA prompts (i.e., prompts delivered at "random" intervals throughout the day from 8:00 a.m. through 10:59 p.m. to capture ecological contexts) were delivered each day, 79% of which, on average, were responded to. In addition, participants completed a survey when they were about to smoke a CC. At each prompt, participants completed a 2-min survey assessing craving and other factors not reported here. Participants also responded to a survey at the end of each day (10:00 p.m. daily; these surveys were completed at 10:16 p.m., on average, with $SD = 44$ min); the end-of-day survey assessed number of CCs smoked and whether ECs were used that day (yes/no). The mean compliance rate for end-of-day surveys was 92.1% (range: 57.1% to 100%). Compliance rate on end-of-day survey completion and the average time at which end-of-day surveys were completed across the 7-day observation period did not differ across participants by the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991) score, gender, average daily number of CCs, average EC use level, and average day-level craving ($ps \geq .20$), suggesting no confounding survey completion characteristics with key study variables.

Baseline Time-Invariant Measures

Self-report measures of participant demographic characteristics, cigarette and other tobacco use history, and FTND (Heatherton et al., 1991), a 6-item measure of nicotine dependence severity, were collected prior to the EMA period.

EMA Measures

Craving—CC craving was measured multiple times each day through random EMA prompts. CC craving was also measured in the prompts administered when participants indicated they were about to smoke a CC (α = .86), with 3 items adapted from the Wisconsin Smoking Withdrawal Scale (Cronk & Piasecki, 2010) (e.g., "I had trouble getting cigarettes off my mind"). The response options anchors were 1 = *Not at all*, 3 = *Somewhat*, to 6 = *Extremely*. The three craving items were averaged for each prompt and these prompt-level craving scores were averaged across the two prompt types for each day.

End-of-Day Surveys

Number of CCs smoked—Participants reported the number of CCs they smoked that day.

EC use—Participants indicated whether they used an e-cigarette/vaped that day (yes/no).

All procedures were approved by the university institutional review board.

Analytic Plan

Generalized linear mixed models were used in which EC use on the day level (yes = 1, no = 0) was the outcome. Key predictors were within-subject variation in the number of CCs smoked, within-subject variation in aggregated craving measures at day level (mean of 3 cigarette craving items calculated for available prompts—both random and smoking, then daily average of prompt-level mean craving scores was calculated), and between-subjects variation in nicotine dependence and gender, which was tested in the first model. In the second model, we examined the interaction between between-subjects predictors (gender and nicotine dependence) and within-subject predictors (day-level craving and number of CCs) to assess whether the extent of intraindividual covariation of craving and CCs smoked to EC use differed as a function of gender or level of nicotine dependence. Data were aggregated at the day level (Level 1) nested within participants (Level 2), yielding 78 participants × 7 days = 546 maximum observations. The final model was adjusted for weekend (vs. weekday), gender, and nicotine dependence level (analytic Level 1 number of observations = 501; see Equation 1).

$$\begin{aligned} &\text{Level 1: } P(y_{ti}|x) = \frac{e^{(\beta_{0i}+\beta_{1i}X_{1ti}+\ldots+\beta_{ki}X_{kti})}}{1+e^{(\beta_{0i}+\beta_{1i}X_{1ti}+\ldots+\beta_{ki}X_{kti})}} \\ &\text{Level 2: } \beta_{0i} = \gamma_{00}+\gamma_{0j}Z_i+\ldots+u_{0i} \\ &\ldots \\ &\beta_{ki} = \gamma_{k0} \end{aligned} \quad (1)$$

where $P(y_{ti}|x)$ is the likelihood of EC use given a set of predictors, t counts the repeated measures, i counts individual, X represents Level 1 predictors, and k counts the Level 1 predictors. Z represents Level 2 predictors, j counts the Level 2 predictors, and u_{0i} represents random effects for intercepts. Given the binary outcome, residual variance is assumed to be $\pi^2/3$ (Hall et al., 2001). All day-level predictors were partitioned into within-person (day-level, centered at person mean) and between-person (person-level, centered at grand mean; Curran & Bauer, 2011).[1]

Results

Descriptives

Sample characteristics are shown in Table 1. EC use was reported in 14.47% of all day-level entries in the entire sample. Twenty participants (25.6%) reported EC use at least once during the 7-day study period (n = 79 EC use reported by 20 participants). Among those who reported EC use over the EMA period, the total number of days of EC use was bimodally distributed (modes = 2 and 6 days, ranging from 1 to 7). On average, participants smoked 6.92 CCs per day (SD = 3.02) throughout the EMA period. There were no gender differences in FTND scores (p = .11), vaping history (0 days EC use vs. 1 or more days in the past 30 days; p = .40), or attempts to quit in the past 30 days (p = .94); more male participants reported smoking 6+ cigarettes/day (vs. 5 or less cigs/day) than did female participants (p = .04).

Daily EC and CC Use and the Role of Dependence

Model 1—Results from the first model which tested the "main effects" of each predictor are reported in the second and third columns of Table 2.[2] Controlling for covariates, within-subject variation in number of CCs smoked (i.e., whether one smokes more/less than his or her usual CC level) was not significantly associated with within-person variation in whether or not an EC was used that same day (p = .40). Within-subject variation in craving (i.e., whether one reported higher craving on that day than one's usual craving across the 7-day observation period) was also not significantly associated with EC use that day (p = .26). The time-invariant, between-subjects predictors, nicotine dependence and gender, were not associated with likelihood of EC use (ps > .27).

Model 2—Results from the second model that added the interaction terms can be found in the fourth and fifth columns of Table 2. Gender significantly moderated the association between craving and EC use on a given day (odds ratio [OR] = 13.39, p = .03). For males, the within-person variation in day-level average craving across the seven days was not associated with EC use that day (OR = .70, p = .68). For females, on the days that they reported higher craving than their usual levels, the likelihood of their EC use that day was significantly heightened. Specifically, each increase in one point on the craving scale was

[1]The between-subject predictors (e.g., gender and FTND scores) are included in the Level 2 equation as Z_j (time-invariant, Level 2, or between-subject predictors), to capture effects of Level 2 predictors of the likelihood of daily vaping when all within-subject predictors are equal to 0; the parameter estimates of time-invariant predictors (γ_{0j}) represent the effects of these predictors on the average likelihood of EC use across the seven days for each participant (i.e., β_{0j}) after all within-subject predictors are held constant.
[2]We also examined how gender and FTND are bivariately related to EC use in two separate multilevel models that excluded other covariates; neither bivariate association of gender (p = .72) nor FTND (p = .63) to EC use was significant.

associated with 13 times greater odds of using an EC that day ($OR = 13.39$, $p = .03$) in women, relative to the odds of EC use among men. Gender did not moderate the intraindividual covariation between CC and EC use and nicotine dependence did not moderate the relation of either craving or CC use to EC use (see Table 2).

Discussion

More than one fourth of this sample reported EC use during the study, suggesting that dual use may be common among KAEA smokers. In this sample of KAEA smokers, we did not find evidence of the hypothesized inverse intraindividual association between EC and CC use. Thus, these findings do not support the notions that: (a) KAEAs are motivated to use ECs as a substitute for smoking on days in which they smoke less, or (b) EC use helps KAEAs smoke less than they normally would without ECs. Given that available naturalistic between-subjects studies show inconsistent results (Dutra & Glantz, 2014; Etter & Bullen, 2011; Grana et al., 2014; Pokhrel et al., 2013; Vickerman et al., 2013) and our within-subject study showed null findings, we cannot rule out the possibility that ECs are not helpful in reducing smoking among those not motivated to quit or substantially reduce their CC use.

Notably, our findings that gender moderated the intraindividual coupling of CC craving with EC use raise the possibility that ECs might be used to relieve heightened CC cravings for female KAEA smokers but not for males. Research has shown that women may be more sensitive to smoking-related sensory stimulation (i.e., denicotinized cigarettes) effects on craving suppression than men (Barrett, 2010). The sensations of EC aerosol in the airways and hand-and-mouth movements of EC use may perhaps satiate craving for women, which could underlie our observation of greater likelihood of EC use on days with higher craving (Perkins, Karelitz, Giedgowd, & Conklin, 2013). Analyses of gender differences in baseline characteristics suggest no confounds between gender and baseline factors that could increase the propensity to use ECs to suppress craving, including smoking heaviness, recent desire to quit, and dependence.

If replicated and extended, the gender differences found raise the possibility that female KAEA smokers (and perhaps female smokers of other races/age groups) may be motivated to use ECs during periods of more intense craving for CCs. Hence, this population may be accepting of clinical interventions that utilize ECs for harm reduction. However, because we did not find that EC use was associated with lower smoking rates in both genders, the efficacy of ECs as a method for reducing CC intake in dual-using women remains unproven. Future research utilizing experimental and naturalistic methods may be necessary to isolate whether factors that provoke states of high craving (e.g., nicotine deprivation) acutely motivate EC vaping.

Analyses of nicotine dependence severity as a moderator of EC-CC relations did not yield significant results; hence, even the more dependent smokers in this young adult sample were not more likely to use ECs on days with less CC use and more craving. Perhaps EC use among emerging adult smokers could be socially determined and tied to desires to connect with the increasingly popular subculture of vaping (Sussman et al., 2014), rather than physiologically-based drives to vape to replace acute nicotine depletion during periods of

CC smoking deprivation more prominent in older heavier smokers. Further, EC dependence may also be an individual difference characteristic that could affect the motivation to vape on days in which CC consumption is limited, which should be addressed in future work.

The null intraindividual covariation between EC and CC use in this study should be interpreted in light of several caveats. Due to the small frequency of EC use days (~15% of day-level prompts) and low proportion of the sample reporting any EC use (n = 20, ~26% of the participants), we may have lacked sufficient power. In addition, the exact timing, amount of EC use, and reasons for each EC use (e.g., motivated to reduce/quit smoking) within each day were not assessed. Also, we might have missed the important temporal relationship between EC and CC use, since we aggregated the data by the day because EC use was only assessed in the end-of-day EMA prompt. The covariation between these two products with each other or with CC craving may be observed at a more microtemporal interval (e.g., hour level) and/or only in certain contexts (e.g., with friends or at a bar), which could not have been captured with the current design. We did not have information on our participants' motivation for using ECs at baseline or during the week of observation (e.g., to alleviate withdrawal symptoms or to reduce smoking); therefore, we are unable to determine whether significant associations would be observed in different contexts and/or samples. The effect of CC deprivation on EC substitution and vice versa may differ for certain ethnic groups. For example, those of Korean descent have been shown to metabolize nicotine more slowly and place a greater weight on external sociocultural (vs. internal addiction-based) effects of tobacco use (Berg, Mason, Boettcher, Hatsukami, & Murphy, 2010; Djordjevic et al., 2013; Kwon et al., 2001). Therefore, robust cravings and compulsions for satiation that may motivate EC use may not be present in the KAEA population. Finally, for young adult smokers like those in our study, CC use history is not likely to be as established as older adult smokers who may have developed a stronger motivation to seek methods that provide pharmacological or sensorimotor satiation (e.g., ECs) during periods of CC use reduction. These limitations warrant future investigations to examine such research questions more thoroughly.

In sum, this within-subject study does not provide support for the hypothesis that EC use helps reduce CC smoking quantity, at least at the day level and among KAEA smokers. However, craving for CCs may play a role in motivation to vape among KAEA female smokers. Future investigation in other ethnic groups, age strata, populations, contexts, and methodologies is warranted to elucidate the nature and direction of the relation of EC to CC use on a microtemporal level among dual users.

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Table 1

Sample Characteristics

	M (*SD*)	*N* (%)
Baseline person-level variables		
Age	22.40 (1.77)	
Female		22 (28.21%)
Employment status		
Full-time student		17 (21.79)
Part-time student, part-time employed		12 (15.38)
Full-time student, full-time employed		11 (14.10)
Employed part-time		5 (6.41)
Employed full-time		25 (32.05)
Not employed, looking for work		8 (10.26)
FTND	2.10 (1.92)	
Smoked a full cigarette prior to age 17 years		52 (66.67)
Number of cigarettes per day during the past 30 days		
2–5 cigs		27 (34.62)
6–10 cigs		37 (47.44)
11–20 cigs		13 (16.67)
20+ cigs		1 (1.28)
Participants reporting any EC use		20 (25.64%)
EMA day-level variables		
Days EC reported (% of days during which EC use was reported)		79 (14.47%)
Average number of CC smoked	6.92 (3.02)	
Average daily mean: craving (1–6)	1.87 (.76)	

Note. Person level (Level 2) $N = 78$. Day level (Level 1) $N = 501$. FTND = Fagerström Test for Nicotine Dependence; EC = electronic cigarettes; CC = combustible cigarettes.

Table 2

Predicting EC Use With Within-Subject Variation in CC Use Within the Same Day (Level 1 N = 501)

	Model 1 *OR*	95% CI	Model 2 *OR*	95% CI
Within subject				
Weekend	2.16	[.78, 6.00]	2.13	[.75, 6.08]
Number of CCs (0 = person mean)	1.15	[.82, 1.61]	1.17	[.82, 1.67]
Day-mean craving (0 = person mean)	2.06	[.59, 7.19]	.70	[.13, 3.72]
Between subject				
Female	.08	[.01, 7.66]	.009*	[.001, .75]
FTND (0 = 2.10, grand mean)	.83	[.26, 2.66]	.35	[.04, 2.75]
Number of CCs (0 = 6.92, grand mean)	.71	[.34, 1.49]	.72	[.34, 1.50]
Craving (0 = 1.87, grand mean)	2.70	[.14, 51.63]	1.95	[.11, 34.88]
Cross-level interaction				
Day-Mean Craving × Female			13.39*	[1.14, 157.13]
Day-Mean Craving × FTND			1.75	[.70, 4.40]
Number of CCs × Female			1.97	[.24, 16.33]
Number of CC × FTND			.88	[.67, 1.15]

Note. Between-subject predictors were centered at means across all participants. Within-subject predictors were centered at person-specific means. *OR* = odds ratios; CI = confidence interval; FTND = Fagerström Test for Nicotine Dependence; ECs = electronic cigarettes; CCs = combustible cigarettes.

* $p < .05$.