



Physical activity among adolescent tobacco and electronic cigarette users: Cross-sectional findings from the Population Assessment of Tobacco and Health study

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ABSTRACT

Research examining relationships between protective health behaviors and tobacco use offers valuable insight regarding the behavior profiles of product users. In particular, protective health behavior trends among adolescent e-cigarette users have not been examined thoroughly to date. This study investigates physical activity patterns among adolescent e-cigarette users, smokers, and dual users of both products, as compared with never users of tobacco products.

Data were collected from 8383 youth participants (12–17 years of age) enrolled in Wave 2 (2014–2015) of the nationally-representative Population Assessment of Tobacco and Health Study. Relationships between use of tobacco products and physical activity were examined via weighted multivariable logistic regression procedures. Compared with never users, each product use group demonstrated an increased likelihood to abstain from moderate-vigorous physical activity. While dual users (aOR = 0.52; 95% CI: 0.30–0.85) and smokers (aOR = 0.53; 95% CI: 0.35–0.71) were less likely than never users to participate in vigorous physical activity, no differences were observed between e-cigarette and never users (aOR = 1.04; 95% CI: 0.74–1.47). Dual users consistently demonstrated the lowest likelihood of physical activity participation.

In conclusion, e-cigarette users were more likely to abstain from moderate-vigorous physical activity participation than never users. However, results did not indicate differences in vigorous or muscle-strengthening physical activity participation between e-cigarette users and never users. Though findings specific to moderate-vigorous physical activity demonstrate a behavioral similarity between e-cigarette users and smokers, key differences in vigorous physical activity were observed. Comparatively low physical activity among dual users suggests existence of a behavior profile gradient according to product use.

1. Introduction

The prevalence of electronic cigarette (e-cigarette) use among middle and high school students in the U.S has escalated nearly 10-fold between 2011 and 2015 (Singh et al., 2016). An estimated 1.73 million high school students and 390,000 middle school students in the U.S. used e-cigarettes in 2017, solidifying e-cigarettes as the most frequently used tobacco product among adolescents (Wang et al., 2018). Though a substantial body of research has revealed a variety of health consequences associated with e-cigarette use (e.g., inhalation toxicity, exposure to nicotine and toxicants, impaired cardiovascular and respiratory function) (Grana et al., 2014), e-cigarettes produce considerably lower concentrations of carcinogenic compounds

commonly identified in combustible cigarettes (hereafter ‘cigarettes’) (Goniewicz et al., 2014). Thus, e-cigarettes are perceived as less harmful alternatives to cigarettes, and are marketed as such (Paek et al., 2014). The degree to which e-cigarettes may positively or adversely impact public health has raised controversy. In adult populations, e-cigarettes have garnered rising popularity among current smokers looking to quit, hypothetically offering harm reduction benefits in the event these smokers switch completely to e-cigarettes (Zhu et al., 2017). However, e-cigarette use is common among young never smokers (Chapman and Wu, 2014), therefore presenting concerns that extend beyond the traditional harm-reduction substitution for cigarettes. Adolescent e-cigarette use promotes nicotine dependence, which is concerning in light of the detriment nicotine has on adolescent brain

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development (Yuan et al., 2015). Additionally, e-cigarette use during adolescence may increase susceptibility to future cigarette smoking (Rigotti, 2015). Taken together with recent proliferation in e-cigarette use by young people, prevention tactics aiming to diminish the influence of e-cigarette use on the adolescent health are warranted.

To identify susceptible adolescents for the efficient allocation of limited prevention resources, there is a need for examining the risk factors associated with e-cigarette use. Much like drugs of abuse, similarities between sociodemographic and behavioral predictors of cigarette and e-cigarette use among adolescents have been reported, and include: male gender; low socioeconomic status; peer and family tobacco use; emotional dysregulation; sensation-seeking behavior; and alcohol and other drug use (Dunbar et al., 2017). However, a growing body of literature has produced compelling evidence demonstrating a contrast in risk behavior profiles between adolescent smokers and e-cigarette users (Barrington-Trimis et al., 2015; Wills et al., 2015). Such observations support speculation that adolescents who try e-cigarettes generally value their health more so than adolescent smokers. Under this theoretical model, their substance use choices are likely to be motivated more by health concerns, thereby diminishing the desirability of cigarettes.

In order to clarify conflicting findings currently comprising the literature, behavior profiles must be explored at greater lengths. One such behavior is participation in physical activity. Regarding combustible tobacco use among adolescents, cross sectional epidemiologic studies have observed inverse associations between smoking and physical activity (Marti and Vartiainen, 1989; Coulson et al., 1997; Holmen et al., 2002), while longitudinal findings indicate a decreased risk of smoking initiation among physically active youths (Kelder et al., 1994; Aaron et al., 1995; Audrain-McGovern et al., 2003; Leatherdale et al., 2008). Beyond the considerable health implications attributable to each behavior (West, 2017; Warburton and Bredin, 2017), the apparent association between smoking and physical activity is consistent within the overarching behavior profile evidence base: adolescents who partake in combustible tobacco use often participate in health-compromising behaviors (Wellman et al., 2016).

Whereas the association between adolescent smoking and physical activity participation has undergone scrutiny, comparatively few studies have examined the association between physical activity and e-cigarette use. While Dunbar and colleagues reported similarities in physical activity participation between exclusive e-cigarette users and exclusive smokers in a sample of youth residing in California (Dunbar et al., 2017), a recent publication examining a cohort of Canadian youth reported greater odds of daily physical activity participation among e-cigarette users as compared to non-users of e-cigarettes (Milicic et al., 2017). These findings suggest a difference may exist in physical activity participation between adolescent smokers and e-cigarette users, possibly signifying a behavioral profile contrast between users of the two products. Additionally, their findings could conceivably influence public policy decisions. Whereas the allocation of tobacco prevention resources towards individuals that frequently participate in health-compromising behaviors has successfully reduced smoking among youth and adolescents, a parallel approach may not be as effective in targeting individuals that are prone to initiating e-cigarette use.

In this study, data was analyzed from a nationally representative sample of adolescents aged 12–17 in the U.S., examining the likelihood of physical activity participation according to four categories of tobacco product use: never users of any combustible or non-combustible tobacco products, exclusive e-cigarette users, exclusive cigarette smokers, and dual users of both e-cigarettes and cigarettes. In performing this analysis, the primary objectives were to quantify trends in physical activity participation among adolescent e-cigarette users compared directly with never users of any tobacco products, as well as to examine possible differences in activity among exclusive e-cigarette users and exclusive smokers in reference to never users of any tobacco products.

Additionally, physical activity among adolescent dual users of cigarettes and e-cigarettes was contrasted against never users of any tobacco products. This allowed for examination of a hypothetical risk profile dose-response relationship across tobacco user groups, of which dual users may comprise the highest risk profile category, as has been observed previously (Dunbar et al., 2017; Wills et al., 2015; Demissie et al., 2017). Based on the existing research paradigm surrounding behavior and risk profiles among tobacco product users (Dunbar et al., 2017; Wills et al., 2015; Demissie et al., 2017), the odds of participating in physical activity were hypothesized to be greatest among never users of tobacco products and least among dual users of cigarettes and e-cigarettes. In light of the damaging influence of tobacco combustion on lung function and physical fitness (Gold et al., 1996; Papatthanasou et al., 2014), it was also hypothesized that exclusive cigarette smokers would be less physically active compared to e-cigarette users.

2. Material & methods

2.1. Study population

A cross-sectional analysis of data from Wave 2 (2014–2015) of the Population Assessment of Tobacco and Health (PATH) Study was performed. The PATH Study is an ongoing longitudinal cohort study of non-institutionalized U.S. residents ages 12 and older that provides surveillance data encompassing tobacco product use and the associated factors and health outcomes within the U.S. population. The PATH Study utilized address-based area-probability sampling in conjunction with sophisticated weighting techniques, providing optimal generalizability to the non-institutionalized civilian U.S. population. Interviews are completed by youth respondents and their parents using Audio Computer-Assisted Self-Interviewing (ACASI). Further details of the PATH Study design and methods are published elsewhere (Hyland et al., 2017).

The analysis was restricted to Wave 2 youth participants ($N = 12,172$). At baseline, PATH study investigators enrolled 13,651 U.S. adolescents into the Wave 1 study cohort (78.4% weighted response rate); 10,081 of the youth participants that were eligible for continued observation were retained during the Wave 2 survey process, and an additional 2091 new youth were successfully recruited at Wave 2 (US Department of Health and Human Services, 2017). The Wave 2 weighted response rate among Wave 1 participants was 87% (US Department of Health and Human Services, 2017). For youth participants, informed consent was obtained through parental consent and adolescent assent. All study procedures were approved by Westat's Institutional Review Board.

2.2. Analytical sample

The PATH Study Wave 2 youth cohort consisted of 12,172 youth participants. In determining the final analytic sample, 3024 participants were initially excluded for failing to meet basic inclusion criteria regarding product use (e.g., former smokers, former e-cigarette users, poly tobacco product users, etc.). Of those 9148 eligible participants, an additional 135 were excluded due to a lack of survey response for any of the three follow-up questions relating to physical activity; another 8 participants were excluded because of compromised physical capabilities that could have prevented those individuals from participating in physical activity regardless of their tobacco product use. Finally, participants lacking complete information for the set of covariates included in the analysis were excluded from the study. Data from 622 respondents were excluded for missing data for gender ($n = 17$), race/ethnicity ($n = 220$), spending money ($n = 70$), BMI ($n = 31$), asthma ($n = 22$), externalizing disorders ($n = 161$) and internalizing disorders ($n = 101$). The final analytic sample consisted of 8383 youth participants ages 12–17 from Wave 2 of the PATH Study (Fig. 1). Compared to those excluded ($n = 3789$), members of the analytic sample tended to

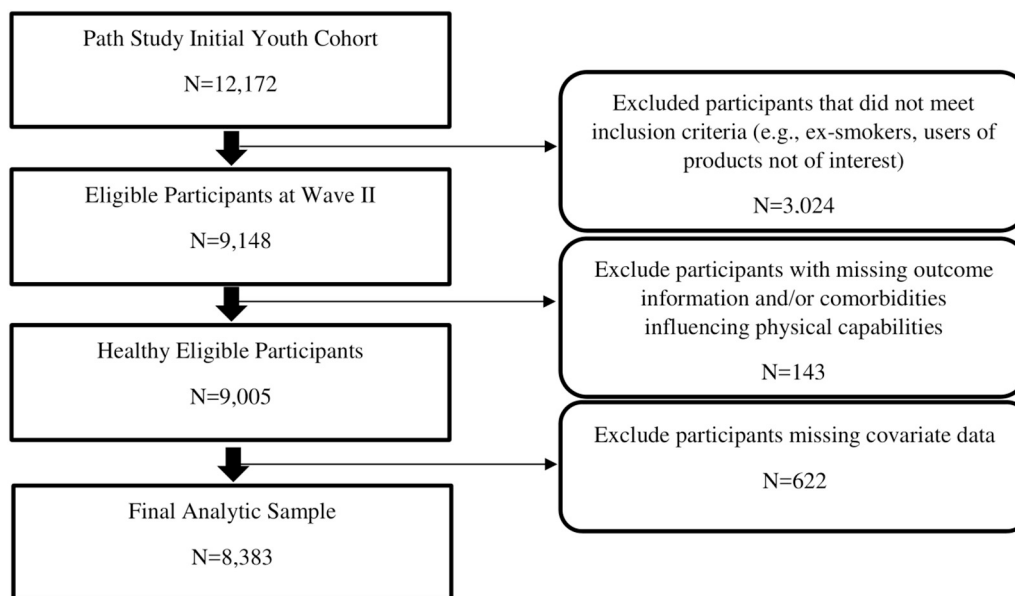


Fig. 1. Analytic sample exclusion criteria flow-chart, Wave 2 (2014–2015) PATH Study participants.

be younger, reported lesser allotments of weekly spending money, and were less frequently past users of cigarettes and e-cigarettes.

2.3. Measures

2.3.1. Categories of tobacco product users

Current exclusive use of tobacco products served as the primary exposure variable for these analyses, and was determined from responses to survey items regarding ever use of a specified tobacco product (dichotomous as No = 0, Yes = 1) and past 30-day product use (0–30 days). Youth participants were asked about use of 12 tobacco products: cigarettes, e-cigarettes, traditional cigars, cigarillos, filtered cigars, pipe, hookah, smokeless tobacco, snus pouches, kreteks, bidis, and dissolvable tobacco. Youth respondents who answered ‘Yes’ to the question “Have you ever tried cigarette smoking, even one or two puffs?”, ≥ 1 to the question “In the past 30 days, on how many days did you smoke cigarettes?”, and reported no prior use of any other tobacco product (including e-cigarettes) were classified as current exclusive smokers (hereafter ‘smokers’). Respondents who answered ‘Yes’ to the question “Have you ever used an electronic nicotine product, even one or two times?”, ≥ 1 to the question “In the past 30 days, on how many days did you use an e-cigarette?”, and reported no prior use of any other tobacco products were classified as current exclusive e-cigarette users (hereafter ‘e-cigarette users’). Those respondents who reported simultaneous current cigarette and current e-cigarette use (as previously defined) that likewise reported never having used any other tobacco products were classified accordingly as dual users of cigarettes and e-cigarettes (hereafter ‘dual users’). Participants that reported no prior use of any tobacco products were classified as ‘never users’ (comparator group).

2.3.2. Outcome variables of physical activity

For the purposes of this analysis, we examined 7-day frequencies of self-reported moderate-to-vigorous physical activity (MVPA), vigorous physical activity (VPA), and muscle-strengthening physical activity (MSPA). Each metric of physical activity was assessed according to participant responses to three separate survey items; responses were coded to align with physical activity recommendations from the 2008 Physical Activity Guidelines for Americans (US Department of Health and Human Services, 2008), which include the following (Wang et al., 2018): children and adolescents should do 60 min or more of physical

activity daily (Grana et al., 2014); children and adolescents should participate in vigorous-intensity physical activity at least 3 days a week (Goniewicz et al., 2014); children and adolescents should participate in muscle and bone-strengthening physical activity on at least 3 days of the week.

The frequency of MVPA was assessed with the following question: “During the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?”. VPA was estimated by the following question: “On how many of the past 7 days did you exercise or participate in physical activity for at least 20 minutes that made you sweat and breathe hard, such as basketball, soccer, running, swimming laps, fast bicycling, fast dancing, or similar aerobic activities?”. Regarding MSPA, youth participants were asked: “On how many of the past 7 days did you do exercises to strengthen or tone your muscles, such as push-ups, sit-ups, or weight lifting?”. Participant responses for each question ranged from ‘0 days’ to ‘7 days’. Each of the three questions derive from the Youth Risk Behavior Survey (YRBS) utilized by the CDC’s Youth Risk Behavior Surveillance System (Heath et al., 1993) The question assessing MVPA has previously been validated against continuous seven-day accelerometry measurement in adolescent populations (Prochaska et al., 2001; Ridgers et al., 2012; Murphy et al., 2015) and is commonly utilized in observational studies among youth; additionally, some research supports the validity of the question pertaining to VPA (Troped et al., 2007), and analogous questions targeting VPA have displayed acceptable validity within adolescents (Prochaska et al., 2001; Lee et al., 2011). Research examining the validity of self-report instruments for the assessment of MSPA in adolescents is currently lacking. Dichotomous outcome variables were established for each physical activity metric in alignment with the previously mentioned recommendations (US Department of Health and Human Services, 2008), whereupon study participants were categorized and coded as either meeting the recommendation (‘Yes’ = 1) or failing to meet the recommendation (‘No’ = 0).

2.3.3. Covariates

Control variables were determined based on known confounders in the published literature encompassing cigarette smoking, e-cigarette use and physical activity. These included age (Singh et al., 2016; Marti and Vartiainen, 1989; Coulson et al., 1997; Holmen et al., 2002; Kelder et al., 1994; Aaron et al., 1995), gender (female, male), race/ethnicity (White, Black, Hispanic, Other), spending money (continuous), BMI

Table 1

Descriptive statistics and Chi-square tests of significance for a sample of youth from Wave 2 (2014–2015) of the PATH Study, stratified by tobacco product user groups ($n = 8383$).

	Never users (a)	e-Cigarette users (b)	Smokers (c)	Dual users (d)
	$n = 7988$	$n = 160$	$n = 157$	$n = 78$
Age				
12–14	56.59 (4561) ^{bcd}	20.67 (35) ^{acd}	12.18 (19) ^{ab}	9.55 (9) ^{ab}
15–17	43.41 (3427) ^{bcd}	79.33 (125) ^{acd}	87.82 (138) ^{ab}	90.45 (69) ^{ab}
Gender				
Male	50.21 (4004) ^{bc}	57.89 (92) ^{ac}	33.73 (52) ^{ab}	45.52 (37)
Female	49.79 (3984) ^{bc}	42.11 (68) ^{ac}	66.27 (105) ^{ab}	54.48 (41)
Race/ethnicity				
Non-Hispanic White	53.65 (3834) ^{bcd}	68.52 (104) ^a	71.29 (99) ^a	77.59 (55) ^a
Non-Hispanic Black	13.64 (1080) ^{bcd}	6.78 (7) ^a	6.58 (10) ^a	3.47 (2) ^a
Hispanic	22.59 (2325) ^{bcd}	17.13 (36) ^a	19.23 (39) ^a	13.48 (14) ^a
Other	10.12 (749) ^{bcd}	7.58 (13) ^a	2.91 (9) ^a	5.46 (7) ^a
Spending money				
\$0	37.99 (3021) ^{bcd}	22.81 (38) ^a	23.96 (38) ^a	16.89 (14) ^a
\$1–20	40.85 (3282) ^{bcd}	27.43 (42) ^a	27.59 (47) ^a	29.86 (23) ^a
\$21–100	15.55 (1233) ^{bcd}	32.10 (56) ^a	28.81 (45) ^a	28.27 (22) ^a
> \$100	5.61 (452) ^{bcd}	17.65 (24) ^a	19.63 (27) ^a	24.97 (19) ^a
BMI (kg/m ²)				
< 18.5	21.70 (1661) ^{bcd}	7.43 (12) ^a	6.83 (12) ^a	7.47 (7) ^a
18.5–24.9	56.65 (4478) ^{bcd}	66.81 (106) ^a	59.60 (90) ^a	61.09 (45) ^a
25.0–29.9	14.08 (1197) ^{bcd}	13.96 (22) ^a	18.34 (30) ^a	18.87 (17) ^a
≥ 30.0	7.57 (652) ^{bcd}	11.80 (20) ^a	15.23 (25) ^a	12.57 (9) ^a
Asthma*				
Yes	17.25 (1399)	19.69 (33)	15.24 (24)	15.74 (14)
No	82.75 (6589)	80.31 (127)	84.76 (133)	84.26 (64)
GAIN internalizing scale				
Low	52.09 (4204) ^{bcd}	31.22 (51) ^{ad}	24.89 (41) ^{ad}	35.39 (29) ^{ac}
Moderate	27.95 (2203) ^{bcd}	28.64 (47) ^{ad}	28.35 (44) ^{ad}	16.22 (13) ^{ac}
High	19.96 (1581) ^{bcd}	40.14 (62) ^{ad}	46.76 (72) ^{ad}	48.39 (36) ^{ac}
GAIN externalizing scale				
Low	56.73 (4574) ^{bcd}	28.48 (47) ^a	32.62 (54) ^a	32.58 (26) ^a
Moderate	36.70 (2887) ^{bcd}	52.01 (81) ^a	41.58 (62) ^a	34.85 (25) ^a
High	6.57 (527) ^{bcd}	19.51 (32) ^a	25.80 (41) ^a	32.58 (27) ^a
Product use frequency†				
< 5 days/month	–	67.69 (111) ^{cd}	53.63 (83) ^{bd}	26.55 (20) ^{bc}
≥ 5 days/month	–	32.31 (49) ^{cd}	46.37 (74) ^{bd}	73.45 (58) ^{bc}

Columns display weighted % (unweighted n).

Superscript letters denote statistically significant differences in variable distribution between specified user groups ($p < 0.05$).

GAIN = Global Appraisal of Individual Needs—Short Screener.

* Asthma information was ascertained via questionnaire response to the question “Have you ever been told by a doctor, nurse or other health professional that you have asthma?”

† If a dual user uses *either* cigarettes or e-cigarettes ≥ 5 days/month, they are considered a ≥ 5 days/month user.

(continuous) asthma (yes/no), externalizing problems (low, moderate, high), and internalizing problems (low, moderate, high). In supplemental models, product use frequency (< 5 or ≥ 5 days/30 days) was examined as an additional covariate.

Developed via the Global Appraisal of Individual Needs — Short Screener (GAIN-SS) (Dennis et al., 2006), the externalizing and internalizing problem variables characterize the severity of mental health ailments facing participants. The following thresholds were used to categorize participants for each variable: 0–1 symptoms in the past year (low), 2–3 symptoms in the past year (moderate) and 4+ symptoms in the past year (high). Further details have previously been published out of the PATH Study (Conway et al., 2017; Silveira et al., 2019; Pearson et al., 2017).

2.4. Statistical methods

Relevant descriptive characteristics of the analytic sample were described through weighted frequency distributions (Table 1). Pearson chi-square tests of independence were used to explore differences in the distribution of descriptive characteristics between each tobacco user group. During primary data analysis, weighted multivariate logistic regression modeling was utilized to calculate adjusted prevalence odds ratios (aOR) and 95% confidence intervals (95% CI) as measures of

association between specified tobacco product use and physical activity. Wave 2 cross-sectional weights were employed as specified in the PATH user guide. PATH Study weighting procedures account for oversampling and survey non-response, as well as providing additional data adjustments to match independent population totals for demographic groups based on U.S. Census Bureau data (Kasza et al., 2017). This allows for estimates produced during analysis of the PATH Study cohort to be representative of the civilian, noninstitutionalized U.S. population. In adjusted regression models, covariates were evaluated in both continuous and categorical fashion when applicable, so as to decrease the likelihood of residual confounding. The covariate specification which produced the largest change to the aOR upon inclusion in unadjusted models was chosen for use in the adjusted models. To account for the PATH Study's complex sampling design, all analyses were conducted using survey procedures in SAS version 9.2 (SAS Institute Inc., Cary NC).

3. Results

Characteristics of the final study sample according to categories of tobacco product use are detailed in Tables 1 and 2. Approximately 95% ($n = 7988$) of participants reported never using any tobacco products, while 2.06% ($n = 160$) were exclusive e-cigarette users, 1.87%

Table 2
Physical activity and tobacco use prevalence estimates for a sample of youth from Wave 2 (2014–2015) of the PATH Study, stratified by tobacco product user groups and age groups (n = 8383).

	Overall	Tobacco use				Age	
		Never users	e-Cigarette users	Smokers	Dual users	12–14 year olds	15–17 year olds
	n = 8383	n = 7988	n = 160	n = 157	n = 78	n = 4624	n = 3759
Moderate-vigorous physical activity*							
No. of days/week	4.22 (4.16–4.28)	4.25 (4.19–4.31)	3.81 (3.47–4.15)	3.50 (3.07–3.93)	3.27 (2.70–3.84)	4.36 (4.28–4.43)	4.06 (3.97–4.14)
7 days/week	23.71 (1975)	23.98 (1901)	19.98 (33)	17.28 (28)	17.00 (13)	25.60 (1179)	21.44 (796)
Vigorous physical activity†							
No. of days/week	3.98 (3.91–4.04)	4.01 (3.94–4.08)	3.85 (3.49–4.20)	2.80 (2.37–3.22)	2.90 (2.30–3.49)	4.18 (4.10–4.26)	3.73 (3.64–3.82)
≥ 3 days/week	69.90 (5844)	70.45 (5613)	70.36 (112)	49.87 (79)	52.62 (40)	73.12 (3359)	66.02 (2485)
Muscle-strengthening physical activity‡							
No. of days/week	2.81 (2.74–2.89)	2.82 (2.74–2.90)	3.16 (2.79–3.53)	2.32 (1.92–2.72)	2.46 (1.80–3.12)	2.85 (2.75–2.95)	2.77 (2.67–2.87)
≥ 3 days/week	49.91 (4223)	49.97 (4033)	56.54 (88)	45.19 (70)	38.81 (32)	49.70 (2312)	50.16 (1911)
Past 30 day exclusive e-cigarette use	2.06 (160)	–	–	–	–	0.78 (35)	3.60 (125)
Past 30 day exclusive cigarette use	1.87 (157)	–	–	–	–	0.42 (19)	3.61 (138)
Past 30 day dual use	0.93 (78)	–	–	–	–	0.16 (9)	1.86 (69)

Columns display weighted means (95% CL) or weighted % (unweighted n).

CL = confidence limit for the weighted mean.

* Based on the question “During the past 7 days, on how many days were you physically active for a total of at least 60 min per day?”

† Based on the question “On how many of the past 7 days did you exercise or participate in physical activity for at least 20 min that made you sweat and breathe hard, such as basketball, soccer, running, swimming laps, fast bicycling, fast dancing, or similar aerobic activities?”

‡ Based on the question “On how many of the past 7 days did you do exercises to strengthen or tone your muscles, such as push-ups, sit-ups, or weight lifting?”

(n = 157) were exclusive smokers, and 0.93% (n = 78) were dual users of both products. Overall, tobacco product users were older, maintained a higher proportion of white participants, and reported greater amounts of weekly spending money as compared to never users. In comparison to never users (50.21% male) and dual users (45.52% male), a larger proportion of e-cigarette users were male (57.89%), whereas a greater proportion of smokers were female (66.27%). User groups varied in their frequency of product use: 46.37% of smokers and 32.31% of e-cigarette users reported product use ≥ 5 times in the past 30 days. In contrast, a majority (73.45%) of dual users consumed at least one of the two tobacco products ≥ 5 times in the past 30 days. Regarding physical activity participation, a higher proportion of never users (23.98%) reported daily MVPA participation ≥ 60 min compared to e-cigarette users (19.98%), smokers (17.28%), or dual users (17.00%); similar percentages of never users (70.45%) and e-cigarette users (70.36%) reportedly met the current VPA guideline, compared to lower proportions of smokers (49.87%) and dual users (52.62%); and e-cigarette users (56.54%) more commonly reported participation in MSPA on ≥ 3 days compared to all other user groups.

Table 3 displays logistic regression results following adjustment for age, gender, race-ethnicity, spending money, BMI, asthma status, externalizing disorders, and internalizing disorders. In reference to never users, dual users (aOR = 2.49; 95% CI: 1.24–4.99), e-cigarette users (aOR = 2.01; 95% CI: 1.21–3.36) and smokers (aOR = 1.90; 95% CI: 1.05–3.45) were more likely to abstain from any bouts of MVPA ≥ 60 min in a typical week. Regarding participation in daily bouts of

MVPA ≥ 60 min, no statistically significant associations were observed among any user groups when compared with never users. The odds of participating in VPA of ≥ 20 min at least 3 times per week were substantially reduced for dual users (aOR = 0.52; 95% CI: 0.30–0.85) and smokers (aOR = 0.53; 95% CI: 0.35–0.71) when compared with never users, while no differences were observed among e-cigarette users and never users. Whereas dual users were less likely than never users to participate in MSPA at least 3 times per week (aOR = 0.61; 95% CI: 0.38–0.96), no differences were observed between e-cigarette users and never users, nor between smokers and never users.

4. Discussion

This study contributes to a growing body of research examining the association between adolescent e-cigarette use and patterns of physical activity. Overall, the results support the notion that adolescent e-cigarette users are less likely to engage in MVPA compared to never users, though they seem no less likely to participate in VPA than never users. And, despite the lack of statistically significant results relevant to MSPA participation among e-cigarette users, they appear to indicate similar odds of participation compared with never users, as opposed to decreased odds. In comparison to e-cigarette users, the physical activity profile of adolescent smokers was strikingly similar regarding MVPA, yet quite different when examining VPA participation; smokers had markedly diminished odds of participating in VPA when compared to never users. Finally, dual users maintained the lowest odds of physical

Table 3

Adjusted OR (aOR) and 95% CI of 7-day moderate-vigorous physical activity (MVPA), vigorous physical activity (VPA), and muscle-strengthening physical activity (MSPA) in adolescent tobacco product users from Wave 2 (2014–2015) of the PATH Study (n = 8383).

Product use	MVPA ≥ 60 min daily		No days with MVPA ≥ 60 min		VPA ≥ 20 min ≥ 3 days/wk		MSPA ≥ 3 days/wk	
	aOR	95%CI	aOR	95%CI	aOR	95%CI	aOR	95%CI
Total sample (n = 8383)								
None	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
Exclusive e-cigarette	0.81	0.54–1.21	2.01	1.21–3.36	1.04	0.74–1.47	1.28	0.93–1.75
Exclusive cigarette	0.82	0.47–1.43	1.90	1.05–3.45	0.53	0.35–0.71	0.93	0.66–1.31
Dual user	0.71	0.38–1.33	2.49	1.24–4.99	0.52	0.30–0.85	0.61	0.36–0.96

Models adjusted for age, gender, race, spending money, BMI, asthma, internalizing disorders, and externalizing disorders.

Bold indicates statistical significance at p < 0.05; aOR = adjusted odds ratio, CI = confidence interval.

activity participation of all three user groups when compared to never users, regardless of the metric.

Findings specific to dual users complement recent publications emphasizing the regularity with which health compromising behaviors are identified among adolescent dual users, even beyond what has been established for exclusive smokers or e-cigarette users (Dunbar et al., 2017; Wills et al., 2015; Leventhal et al., 2015). Such health compromising behaviors may be associated with increased risk of poor health outcomes, signifying the importance of surveillance for both e-cigarette and cigarette use among adolescents, as well as targeted prevention efforts to curtail e-cigarette users from transitioning to dual use.

Though participation in MVPA among youth e-cigarette users did not differ from that of youth smokers, results also suggest that e-cigarette users were more similar to never users and increasingly dissimilar to smokers regarding VPA participation. Notable contrast in VPA participation among e-cigarette users and smokers may lend credence to the hypothesized “healthy effect” of e-cigarettes; that is, the common perception that e-cigarettes have negligible health ramifications may promote their utility, even among youth that would normally avoid tobacco product use altogether. In particular, contrast in VPA involvement is a concern regarding susceptibility to cigarette smoking and other tobacco use among portions of the adolescent population that were previously unaffiliated with such behaviors. Still, it is readily apparent that the association between adolescent e-cigarette use and self-reported MVPA was no different than the association between adolescent smoking and MVPA, indicating behavioral similarities between the user groups as opposed to contrast. Further examination of the relationship between participation in VPA and an individual's health behavior profile could help elucidate the extent to which VPA participation clusters with those behaviors consistently seen in youth that abstain from tobacco use. While strong evidence exists suggesting youth who participate more frequently in MVPA maintain a healthier behavior profile as compared to less active youth (Pate et al., 1996; Sallis and Prochaska, 2000; Nelson and Gordon-Larsen, 2006; Sterdt et al., 2014), correlations between VPA and adolescent behavioral trends have yet to be examined to the fullest extent. Because VPA is often a more accurate self-report measure than MVPA in adolescent populations (Sallis and Saelens, 2000; Corder et al., 2008), it may provide more pertinent information when examining associations between physical activity and health behaviors in adolescent populations.

This study contributes to the growing evidence base encompassing behavioral profiles of tobacco product users. The PATH Study's nationally representative, population-based sample provided a strong foundation from which to conduct the current analysis. While previous studies have been limited by the possibility of additional tobacco product use within their e-cigarette user and smoker categories (Milicic et al., 2017), the present analysis ensured exposure categories were comprised explicitly of specified product use through employment of exclusive product use categories, lessening concerns of spurious results via exposure misclassification. Still, this study is not without limitations. As this was a cross-sectional analysis based on self-report information, the insight provided is limited by a lacking temporal framework, along with the inherent drawbacks of self-reported observational data. Additionally, a number of factors potentially relevant to physical activity and tobacco use were not available for inclusion in the analysis. The addition of constructs such as sensation seeking, individual norms and values, self-efficacy, dietary intake and sedentary behavior would have strengthened the analysis. Therefore, the possibility of omitted variable bias cannot be excluded completely. Thirdly, the classification of tobacco product use (past 30 days) could indicate either consistent product use or experimentation. To combat this, frequency of use (number of days used in past 30 days) was examined and included as a covariate in supplemental models. These results (not published) demonstrated no significant influence on the associations of interest. Finally, estimates of tobacco use prevalence within the analytic sample were lower than what has been reported by

national surveys of youths (i.e. National Youth Tobacco Survey (Singh et al., 2016)). Interestingly, previous research has observed a tendency for household-based surveys to report lower rates of youth tobacco product use compared to school-based surveys (Biglan et al., 2004; Griesler et al., 2008). This trend is corroborated by similarities in tobacco use prevalence between the PATH study and the National Survey on Drug Use and Health (NSDUH), both of which utilize household-based survey methods. Though this phenomenon is not fully understood, social desirability bias may contribute to the observed differences between survey modes: peer norms in a school environment may inflate tobacco use estimates, whereas skepticism towards survey confidentiality may deflate estimates ascertained during a household survey (Biglan et al., 2004). As such, the present findings may be influenced by underreported tobacco use among participants, where by the never user group might include a proportion of tobacco users that misreported product use. However, due to the present analysis' large sample size, it appears unlikely that this concern would exude significant influence on the associations of interest.

The study results offer valuable insight towards a relationship that has not been studied expansively to date. Clearly, MVPA does not provide an all-encompassing view of physical activity behavior among adolescent tobacco product users. Future studies should aim to look at multiple components of physical activity participation when attempting to further the relevant knowledgebase. As the current and antecedent analyses examining adolescent e-cigarette use and physical activity have been cross sectional in nature, longitudinal studies continue to be a pressing need, preferably conducted among a highly generalizable study cohort. Following time accrual over the coming years, the PATH Study youth cohort might provide an optimal setting for a prospective study of the relationships between adolescent e-cigarette use, smoking and physical activity participation. Studies conducted among larger numbers of product users will improve the precision of measures of association, and also offer opportunities for exploratory analyses (i.e., effect modification).

In conclusion, this study observed a confluence of similarities and differences in physical activity among adolescent tobacco product users. Both e-cigarette users and smokers were more likely to abstain from MVPA than never users. Notably, e-cigarette users demonstrated a greater inclination to participate in VPA than did smokers, highlighting a possible behavioral contrast among adolescent smokers and e-cigarette users. Additionally, dual users demonstrated susceptibility to lower physical activity participation than either single product user group. This supports the notion of a behavioral profile gradient where dual users are characterized by poor health behaviors.

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Declaration of Competing Interest

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