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The Association of Global and Disease-Related Stress With Susceptibility to and Use of E-Cigarettes and Marijuana Among Adolescents With Congenital Heart Disease

Kristen R. Fox [1], PhD, Amy K. Ferketich, [2] PhD, Judith A. Groner, [3] MD, Joseph R. Rausch, [1,4] PhD, Vidu Garg, [4,5] MD, Victoria R. Grant, [1] BS, Steven P. Neville, [1] BA, Clifford L. Cua, [6] MD, and Jamie L. Jackson [1,4] PhD

[1]Center for Biobehavioral Health, The Abigail Wexner Research Institute at Nationwide Children's Hospital, Columbus, OH, USA, [2]Division of Epidemiology, College of Public Health, The Ohio State University, Columbus, OH, USA, [3]Department of Pediatrics, Nationwide Children's Hospital, Columbus, OH, USA, [4]Department of Pediatrics, College of Medicine, The Ohio State University, Columbus, OH, USA, [5]The Heart Center and Center for Cardiovascular Research, Nationwide Children's Hospital, Columbus, OH, USA, and [6]The Heart Center, Nationwide Children's Hospital, Columbus, OH, USA

All correspondence concerning this article should be addressed to Kristen R. Fox, PhD, 700 Children's Drive, Columbus, OH 43205, USA. E-mail: kristen.fox@nationwidechildrens.org

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Abstract

Objective Adolescents with congenital heart disease (CHD) are exposed to disease-related stressors and have elevated risk for cardiovascular and cognitive complications that are exacerbated by e-cigarettes and marijuana. The aims of this cross-sectional study are to: (1) identify the association between perceived global and disease-related stress and susceptibility to e-cigarettes and marijuana, (2) determine if the association between stress and susceptibility differs by gender, and (3) explore the association between stress and ever use of e-cigarettes and marijuana among adolescents with CHD; **Methods** Adolescents with CHD ($N = 98$; aged 12–18 years) completed self-report measures of susceptibility to/ever use of e-cigarettes and marijuana and global and disease-related stress; **Results** Susceptibility to e-cigarettes and marijuana was reported by 31.3% and 40.2% of adolescents, respectively. Ever use of e-cigarettes and marijuana was reported by 15.3% and 14.3% of adolescents, respectively. Global stress was associated with susceptibility to and ever use of e-cigarettes and marijuana. Disease-related stress was associated with susceptibility to marijuana. Females reported more global and disease-related stress than males, but the association of stress with susceptibility to e-cigarettes and marijuana did not differ by gender. **Conclusions** Susceptibility to e-cigarettes and marijuana is common among adolescents with CHD and is associated with stress. Future work to examine the longitudinal associations between susceptibility, stress, and use of e-cigarettes and marijuana is warranted. Global stress may be an important consideration in the development of strategies to prevent these risky health behaviors among adolescents with CHD.

Key words: adolescents; congenital heart disease; e-cigarettes; marijuana; stress.

Introduction

Approximately one in 100 infants is born with congenital heart disease (CHD), the most common birth defect worldwide (Van Der Linde et al., 2011). Congenital heart disease varies in complexity, with some forms needing no intervention and others requiring multiple surgeries. All individuals with CHD, regardless of complexity, require lifelong surveillance (Stout et al., 2019). Individuals with CHD have elevated risk of cardiovascular (T. Wang et al., 2019) and cognitive (Feldmann et al., 2021) complications, possibly increasing their vulnerability to potential cardiovascular and cognitive effects of e-cigarettes (e.g., increased blood pressure, difficulty concentrating) (Groner, 2022; Xie et al., 2020) and marijuana (e.g., stroke, poor attentional control) (Paige & Colder, 2020; Parekh et al., 2020). Hence, identifying correlates of (a) susceptibility to future use and (b) history of ever use of e-cigarettes and marijuana is critical for informing prevention strategies to enhance the long-term wellbeing of this cardiovascular and cognitive at-risk population.

Susceptibility to e-cigarette or marijuana use is defined as the absence of a strong commitment to not engage in the behavior in the future (Barrington-Trimis et al., 2020; Strong et al., 2015) and is distinct from ever use, which refers to a lifetime history of using e-cigarettes or marijuana. For example, adolescents may be susceptible to future use but have no lifetime history of use, or adolescents may have a lifetime history of use but no longer endorse susceptibility to future use. Susceptibility predicts future use of e-cigarettes (Bold et al., 2017; Nicksic & Barnes, 2019; Seo et al., 2020) and marijuana (Barrington-Trimis et al., 2020), but correlates of susceptibility to these health risk behaviors among adolescents with CHD are unknown. Adolescents with CHD may view e-cigarettes and marijuana differently than their healthy peers, given unique health risks. Prior work has shown that adolescents with CHD perceive substance use as more harmful for them than those without CHD (Van Deyk et al., 2010). Individuals with CHD also report lower rates of conventional cigarette and marijuana use than healthy individuals (Moons et al., 2019). Because of these differences, whether the same factors associated with e-cigarette and marijuana susceptibility and use among healthy adolescents are applicable for adolescents with CHD requires investigation.

Among healthy adolescents, stress and other mental health symptoms have been associated with e-cigarette and marijuana use. For example, stress during middle school predicts e-cigarette use in high school, particularly for females, (Leventhal et al., 2017), who are more likely to use e-cigarettes to reduce stress (Piñeiro et al., 2016). Further, medically complex youth identify stress reduction as a benefit of marijuana (Brenton et al., 2018), and higher stress is associated with increased marijuana use among youth and young adults (Clendennen et al., 2021), which may vary by gender (Assari, Mistry, Caldwell, et al., 2018).

Compared to peers, adolescents with CHD are more likely to have a mental health disorder (Gonzalez et al., 2021), potentially increasing the risk for e-cigarette or marijuana use. Indeed, poor mental health, including stress, has accounted for the higher prevalence of current e-cigarette use among young adults with a history of asthma compared to those without asthma (Alanazi et al., 2020). Thus, perceived stress may be a particularly important consideration for susceptibility to and use of e-cigarettes and marijuana for other medically complex individuals, such as adolescents with CHD.

Disease-specific stress, in addition to global perceived stress, may also be associated with susceptibility to and use of e-cigarettes and marijuana among adolescents with CHD. Adolescents with CHD are exposed to disease-related stressors (e.g., attending medical appointments, medical procedures), have increased health-related anxiety (Oliver et al., 2020), and experience uncertainty about their illness, which has been associated with emotional distress (Jackson et al., 2017). Disease-related stressors (e.g., worry about long-term health) are associated with increased substance use among adolescent survivors of cancer (Choi et al., 2022). Further, in a study of adults with CHD, those with negative emotional appraisals of CHD had increased odds of current smoking (Fox et al., 2021). Therefore, disease-related stress may be a unique consideration for e-cigarette and marijuana use among adolescents with CHD or other medical complexities.

To address the absence of research on susceptibility to and use of e-cigarettes and marijuana among adolescents with CHD, the present study aims to: (1) identify the association between perceived global and disease-related stress with susceptibility to e-cigarettes and marijuana, (2) determine if the association between stress and susceptibility differs by gender, and (3) explore the association between stress and ever use of e-cigarettes and marijuana.

Methods

Participants and Procedure

A convenience sample of adolescents was identified from outpatient cardiology clinic rosters at a Midwestern pediatric hospital based on clinic schedules and the availability of researchers. Adolescents were screened via medical record review according to the following inclusion criteria: (1) diagnosis of CHD and (2) 12 to 18 years of age. Exclusion criteria included: (1) diagnosis of a genetic syndrome or other

medical condition with multiorgan involvement, (2) cognitive impairment interfering with the ability to complete study procedures as determined by diagnosis of an intellectual disability, neuropsychological test results indicating difficulties with comprehension, or cardiologist assessment of adolescent ability to participate, and (3) preferred language other than English. Eligibility was confirmed by the primary cardiologist before adolescents were approached for participation. After eligibility was confirmed, potential participants were mailed a brief letter that notified them of their eligibility and included instructions on how to opt-out. Study staff contacted those who did not opt-out by phone to describe the study procedures. If potential participants were unreachable by phone, they were approached for participation during their clinic visit. Parents/guardians and participants 18 years of age provided informed consent, and participants <18 years of age provided informed assent. The Institutional Review Board of the study site approved the protocol.

Between April 2021 and April 2022, 127 adolescents were approached for participation and 102 were enrolled, reflecting a recruitment rate of 80.3%. Reasons for decline included lack of interest ($n = 16$) and time demands ($n = 9$). Adolescents who enrolled were not different than adolescents who declined on age ($p = .387$) or gender ($p = .965$). However, adolescents with complex CHD (61.5%) were less likely to enroll than adolescents with simple (96.2%; $p = .002$) or moderate (86.9%; $p = .003$) CHD. After enrolling, one participant requested to withdraw due to time demands; one participant was withdrawn due to screening failure; and two participants were lost to follow-up. A total of 98 adolescents completed an online survey assessing health behaviors and psychosocial functioning either at home ($n = 94$) or during their clinic visit ($n = 4$). Adolescents were informed that their survey responses were confidential, would not be released to their parent/guardian, and would not become part of their medical records. Sample characteristics are presented in Table I. Participants were primarily male (57.1%), had a mean age of 15.2 years ($SD = 1.9$), and had CHD of moderate severity (60.2%).

Table I. *Sample Characteristics and Study Outcomes Presented as M(SD) and %(N) for Continuous and Categorical Variables, Respectively*

	M (SD)/% (*N*)	Observed range
Demographic and clinical characteristics		
Age ($n = 98$)	15.2 (1.9)	12–18
Gender ($n = 98$)		
Male	57.1% (56)	
Female	41.8% (41)	
Non-binary	1.0% (1)	
Race ($n = 98$)[a]		
Asian American	9.2% (9)	
Black or African American	17.3% (17)	
Multiracial	3.1% (3)	
Native American	3.1% (3)	
Other (Puerto Rican)	1.0% (1)	
White or European American	73.5% (72)	
Ethnicity ($n = 93$), Hispanic or Latino	3.2% (3)	
Estimated family income ($n = 98$)	$88,435 ($37,398)	$26,462–$196,259
Household tobacco use ($n = 94$), yes	38.3% (36)	
Lesion severity ($n = 98$)		
Simple	15.3% (15)	
Moderate	60.2% (59)	
Complex	24.5% (24)	
History of any cardiac surgery ($n = 98$), yes	53.1% (52)	
Fontan ($n = 98$), yes	13.3% (13)	
Study outcomes		
Global stress ($n = 97$)	17.3 (8.6)	2.0–40.0
Disease-related stress ($n = 98$)	23.3 (7.8)	13.0–42.0
Susceptible to e-cigarettes ($n = 96$), yes	31.3% (30)	
Ever use of e-cigarettes ($n = 98$), yes	15.3% (15)	
Susceptible to marijuana ($n = 97$), yes	40.2% (39)	
Ever use of marijuana ($n = 98$), yes	14.3% (14)	

[a]Participants were able to select more than one racial category and thus the sum of all categories exceeds 100%.

Measures

Global Stress

The 10-item Perceived Stress Scale (PSS-10) (Cohen & Williamson, 1988) measured global stress over the past month. Participants rated items on a 0 (*Never*) to 4 (*Very Often*) scale. Items are summed to create a total score ranging from 0 to 40, with higher scores reflecting greater perceived stress. Excellent internal consistency reliability was observed ($\alpha = .90$).

Disease-Related Stress

Disease-related stress was assessed with 13 items adapted as CHD stressors (Jackson et al., 2017) for the Responses to Stress Questionnaire (Connor-Smith et al., 2000). Participants rated the extent to which they experienced stress related to various aspects of living with CHD (e.g., "Concerns about whether

medical procedures may be needed in the future," "Going to the doctor for appointments or tests") on a scale from 1 ("Not at all") to 4 ("Very stressful"). Items were summed to create a total score, ranging from 13 to 52. Higher scores indicate greater disease-related stress. Good internal consistency was observed ($\alpha = .87$).

Susceptibility to E-Cigarettes and Marijuana

The four-item Expanded Susceptibility to Smoke Index (Strong et al., 2015) assessed risk for future or continued use of e-cigarettes and marijuana. Participants responded either "Definitely Not," "Probably Not," "Probably Yes," or "Definitely Yes" to items such as, "Do you think that in the future you might experiment with e-cigarettes [marijuana]?" For the present study, item wording was modified to reflect e-cigarettes and marijuana (e.g., "smoke a cigarette" to "use an e-cigarette" and "use marijuana" for e-cigarettes and marijuana, respectively). The wording of Expanded Susceptibility to Smoke Index items has been similarly modified for e-cigarettes and marijuana in other work and has predicted future e-cigarette (Bold et al., 2017) and marijuana (Barrington-Trimis et al., 2020) use. Consistent with procedures for the original Susceptibility to Smoke Index (Pierce et al., 1996) and recent e-cigarette (e.g., Bold et al., 2017) and marijuana (Barrington-Trimis et al., 2020) research, participants were classified as "Not Susceptible" if they responded, "Definitely Not" to all items; participants reporting any other response to one or more items were classified as "Susceptible".

E-Cigarette and Marijuana Use

A single item, "Have you ever tried an e-cigarette, even once or twice? [Yes/No]" from the National Youth Tobacco Survey (Office on Smoking and Health, 2019) assessed ever use of e-cigarettes. The same item was modified to assess ever use of marijuana (i.e., "Have you ever tried marijuana, even once or twice?" [Yes/No]).

Demographic and Clinical Characteristics

Age, race, ethnicity, and gender were self-reported. Response choices for race and ethnicity (see Table I) were consistent with the National Institutes of Health racial and ethnic categories, with the addition of an "Other" option for race. Congenital heart disease lesion severity was abstracted from medical records and was classified as simple (e.g., atrial septal defect), moderate (e.g., tetralogy of Fallot), or complex (e.g., hypoplastic left heart syndrome) (Stout et al., 2019). History of any cardiac surgery was also obtained from medical records. Participants' home addresses were used to estimate annual family income via data from the Federal Financial Institutions Examination Council, which uses loan application information and self-reported census data to approximate yearly family income within a particular census tract (Federal Financial Institutions Examination Council, n.d.). Participants reported if anyone currently living in their home uses cigarettes, e-cigarettes, or smokeless tobacco and were considered positive for household tobacco use if one or more of the products were endorsed.

Statistical Analysis

Missingness was examined, and the number of participants with valid data for each variable is indicated in Table I. For the continuous variables of global ($n = 3$) and disease-related stress ($n = 6$), mean replacement was employed if $\geq 75\%$ of the measure items were available. One participant identified as non-binary in gender and is represented in descriptive and unadjusted analyses but was not included in gender-adjusted models due to the small cell size.

Prior to the analysis of the primary study aims, descriptive statistics and bivariate analyses (i.e., *t*-tests, chi square analyses) characterized the proportion of adolescents who were susceptible to or reported ever use of e-cigarettes and marijuana and assessed gender differences in stress and susceptibility and ever use, respectively. For Aims 1–3, separate logistic regression models for global and disease-related stress were used to determine the associations between stress and susceptibility to and ever use of e-cigarettes and marijuana. For Aims 1 and 2, unadjusted and adjusted models are presented. Model covariates (i.e., gender, income, and household tobacco use) were selected *a priori* based on prior literature examining the association between stress and e-cigarette use among adolescents (Leventhal et al., 2017). Lesion severity was included as a covariate given that one's interest in health risk behaviors may vary as a function of disease status. For Aim 3, covariates were not included in the exploratory models to conserve statistical power due to the small number of participants reporting ever use of e-cigarettes and marijuana. Similarly, gender by stress interactions on e-cigarette and marijuana use were not explored due to the small number of participants endorsing ever use. To facilitate a comparison of the strength of associations between both forms of stress with both e-cigarettes and marijuana, continuous variables (i.e., global stress, disease-related stress, and income) were standardized prior to model entry. Thus, odds ratios reflect the odds of susceptibility or ever use for one standard deviation increase in the continuous independent variable. De-identified data from this study are not available in a public archive but are available upon request as allowable according to institutional IRB standards and are subject to a data use agreement.

Results

Nearly one-third of adolescents ($n = 30$; 31.3%) were susceptible to future or continued use of e-cigarettes, and 15 adolescents (15.3%) reported ever use of e-cigarettes. Most adolescents ($n = 13$; 86.7%) who endorsed ever use of e-cigarettes were also susceptible to future use. The proportion of adolescents who were susceptible to (females: 34.1%; males: 27.8%), $\chi^2(1, N = 95) = 0.45$, $p = .504$, or had ever used (females: 17.1%; males: 14.3%), $\chi^2(1, N = 97) = 0.14$, $p = .708$, e-cigarettes did not differ by gender. Approximately 40% of adolescents ($n = 39$) were susceptible to future or continued use of marijuana, including all 14 adolescents who also reported ever use of marijuana. The proportion of adolescents who were susceptible to (females: 43.9%; males: 36.4%), $\chi^2(1, N = 96) = 0.56$, $p = .455$, or had ever used (females: 17.1%; males: 12.5%), $\chi^2(1, N = 97) = 0.40$, $p = .527$, marijuana did not differ by gender.

Table I presents descriptive statistics for global and disease-related stress. The proportion of adolescents endorsing stress greater than one standard deviation above the sample mean was 16.5% ($n = 16$) and 18.4% ($n = 18$) for global and disease-related stress, respectively. Females ($M = 19.6$, $SD = 8.9$) reported greater global stress than males ($M = 15.3$, $SD = 7.8$), $t(94) = 2.55$, $p = .012$, $d = 0.52$. Females also reported greater disease-related stress ($M = 25.6$, $SD = 7.4$) than males ($M = 21.5$, $SD = 7.7$), $t(95) = 2.59$, $p = .011$, $d = 0.53$. Disease-related stress did not differ by CHD severity, $F(2, 95) = 0.04$, $p = .957$, $\eta^2 < 0.01$, or history of cardiac surgery, $t(96) = -0.12$, $p = .908$, $d = 0.02$. Global and disease-related stress were moderately correlated, $r(97) = .43$, $p < .001$.

Association of Stress With Susceptibility to E-Cigarettes and Marijuana

As shown in Table II, higher global stress was associated with increased odds of susceptibility to e-cigarettes and marijuana in both unadjusted and adjusted models. Higher disease-related stress was associated with increased odds of susceptibility to marijuana in unadjusted and adjusted models, but disease-related stress was not associated with susceptibility to e-cigarettes (see Table II).

Gender Differences in the Association of Stress with Susceptibility to E-Cigarettes and Marijuana

The association of global and disease-related stress with susceptibility to e-cigarettes and marijuana did not differ by gender (see Table II).

Association Between Stress and Ever Use of E-Cigarettes and Marijuana

Global stress was associated with higher odds of ever use of e-cigarettes (OR = 2.65, 95% CI = 1.42, 4.95, $p = .002$) and marijuana (OR = 2.31, 95% CI = 1.25, 4.26, $p = .008$). However, disease-related stress was not associated with ever use of e-cigarettes (OR = 1.48, 95% CI = 0.86, 2.54, $p = .159$) or marijuana (OR = 1.66, 95% CI = 0.94, 2.90, $p = .078$).

Discussion

The present study is the first to investigate susceptibility to e-cigarettes and marijuana among the cardiovascular and cognitive at-risk population of adolescents with CHD. Findings imply that a considerable portion of adolescents with CHD are at risk for initiating or continuing the use of e-cigarettes and marijuana, potentially threatening their cardiovascular and cognitive health. Further, global and disease-related stress were identified as correlates of increased susceptibility to or use of e-cigarettes or marijuana. Ultimately, as susceptibility is associated with future use, these findings may inform strategies to prevent these risky health behaviors among adolescents with CHD.

Susceptibility to future or continued use of e-cigarettes (31%) and marijuana (40%) was common. For e-cigarettes, the rate of susceptibility was comparable to that observed among healthy adolescents (Bold et al., 2017). However, it must be noted that the present study included adolescents reporting ever using e-cigarettes as susceptible if they endorsed items indicating continued risk for use, whereas other research has excluded adolescents reporting ever use from being classified as susceptible. Research on adolescent susceptibility to marijuana as operationalized in the present study is limited, preventing comparisons to healthy adolescents.

In the present study, approximately 15% of adolescents with CHD reported ever using e-cigarettes. This finding contrasts with other work showing that 35% of middle and high school students have ever used an e-cigarette (T. W. Wang et al., 2019). Ever use of marijuana (14%) also appeared to be less common among adolescents with CHD than healthy high school students (Jones et al., 2020). However, Jones et al. considered only older adolescents (i.e., high school age), whereas the current study included younger adolescents who may be less likely to have a history of marijuana use. For both e-cigarettes and marijuana, the potential for underreporting use in research conducted in medical settings must be considered in relation to the potential for overreporting in school-based research (McCambridge & Strang, 2006). In addition, the demographic profile of the present sample does not reflect the general U.S. population, further prohibiting conclusive comparisons between adolescents with CHD and healthy adolescents.

Consistent with findings from work conducted among youth without CHD (Clendennen et al., 2021; Jha & Kraguljac, 2021; Leventhal et al., 2017), the

Table II. *Association of Global and Disease-Related Stress With Susceptibility to E-Cigarettes and Marijuana*

	Global stress			Disease-related stress		
	OR[a]	95% CI	*p*	OR[a]	95% CI	*p*
Susceptibility to e-cigarettes						
Unadjusted Main Effect Model		*n* = 95			*n* = 96	
Stress	2.74	[1.61, 4.66]	.000	1.52	[0.98, 2.37]	.060
Adjusted Main Effect Model		*n* = 90			*n* = 91	
Stress	3.12	[1.65, 5.92]	.000	1.55	[0.95, 2.54]	.079
Gender[b]	0.77	[0.24, 2.44]	.652	0.55	[0.19, 5.29]	.259
Household tobacco use[c]	2.07	[0.68, 6.25]	.199	1.91	[0.69, 5.29]	.211
Family income	1.17	[0.68, 2.02]	.577	1.08	[0.66, 1.79]	.756
Lesion severity, moderate[d]	1.29	[0.27, 6.15]	.751	0.79	[0.20, 3.09]	.733
Lesion severity, complex[d]	2.12	[0.35, 13.08]	.417	1.57	[0.31, 7.87]	.584
Unadjusted Interaction Model		*n* = 94			*n* = 95	
Stress	4.20	[1.57, 11.25]	.004	1.45	[0.71, 2.95]	.309
Gender[b]	1.68	[0.51, 5.49]	.393	0.88	[0.35, 2.24]	.790
Stress × gender	0.49	[0.15, 1.64]	.247	1.00	[0.40, 2.52]	.997
Adjusted Interaction Model		*n* = 90			*n* = 91	
Stress	4.08	[1.50, 11.12]	.006	1.49	[0.72, 3.09]	.289
Gender[b]	0.91	[0.25, 3.35]	.893	0.54	[0.19, 1.55]	.253
Stress × gender	0.61	[0.17, 2.19]	.453	1.09	[0.40, 2.94]	.870
Household tobacco use[c]	1.97	[0.64, 6.05]	.237	1.92	[0.69, 5.31]	.209
Family income	1.15	[0.67, 1.99]	.613	1.90	[0.66, 1.82]	.740
Lesion severity, moderate[d]	1.31	[0.26, 6.50]	.743	0.80	[0.20, 3.13]	.742
Lesion severity, complex[d]	2.20	[0.35, 13.84]	.400	1.56	[0.31, 7.84]	.592
Susceptibility to marijuana						
Unadjusted Main Effect Model		*n* = 96			*n* = 97	
Stress	2.52	[1.54, 4.14]	.000	1.60	[1.05, 2.44]	.030
Adjusted Main Effect Model		*n* = 91			*n* = 92	
Stress	3.05	[1.68, 5.53]	.000	1.63	[1.02, 2.63]	.042
Gender[b]	0.95	[0.32, 2.78]	.922	0.72	[0.27, 1.91]	.505
Household tobacco use[c]	3.03	[1.02, 8.98]	.046	2.52	[0.95, 6.64]	.062
Family income	1.75	[1.00, 3.05]	.051	1.51	[0.93, 2.47]	.100
Lesion severity, moderate[d]	0.85	[0.20, 3.69]	.831	0.66	[0.18, 2.38]	.527
Lesion severity, complex[d]	0.79	[0.13, 4.65]	.791	0.72	[0.15, 3.42]	.681
Unadjusted Interaction Model		*n* = 95			*n* = 96	
Stress	2.41	[1.17, 5.00]	.018	1.03	[0.53, 1.98]	.942
Gender[b]	1.20	[0.46, 3.10]	.709	0.83	[0.35, 1.98]	.672
Stress × gender	1.11	[0.39, 3.19]	.848	2.05	[0.83, 5.06]	.120
Adjusted Interaction Model		*n* = 91			*n* = 92	
Stress	2.57	[1.19, 5.54]	.017	1.02	[0.51, 2.03]	.961
Gender[b]	0.91	[0.31, 2.66]	.860	0.65	[0.24, 1.74]	.390
Stress × gender	1.46	[0.46, 4.62]	.522	2.43	[0.91, 6.46]	.076
Household tobacco use[c]	3.16	[1.06, 9.45]	.040	2.73	[1.01, 7.44]	.049
Family income	1.77	[1.01, 3.12]	.048	1.64	[0.98, 2.74]	.062
Lesion severity, moderate[d]	0.86	[0.20, 3.69]	.843	0.70	[0.19, 2.56]	.591
Lesion severity, complex[d]	0.79	[0.13, 4.66]	.790	0.66	[0.13, 3.19]	.600

[a]Odds ratios are for one standard deviation increase in continuous variables.
[b]Female gender is the reference category.
[c]No household tobacco use is the reference category.
[d]Simple lesion severity is the reference category.

present study also found that susceptibility to and ever use of e-cigarettes and marijuana are related to stress. Global stress was associated with susceptibility to and ever use of both e-cigarettes and marijuana. The observed associations between global stress and susceptibility to and use of e-cigarettes and marijuana may be reflective of adolescents' efforts to cope with stress. Indeed, coping may mediate the association between emotional factors (e.g., distress intolerance, anxiety sensitivity) and increased substance use among adolescents (Cho et al., 2021). Moreover, stress reduction is commonly endorsed by adolescents as a benefit of e-cigarette use (Jha & Kraguljac, 2021). Maladaptive coping methods (e.g., avoidance) are associated with adolescent marijuana use (Lee-Winn et al., 2018), and marijuana cessation is associated

with expectations of increased stress (Metrik et al., 2017).

While global stress was associated with both e-cigarette and marijuana susceptibility and use, disease-related stress was related only to marijuana susceptibility. Adolescents with elevated disease-related stress may perceive marijuana as less harmful to their health than e-cigarettes and thus are more likely to be susceptible to marijuana. Additionally, disease-related stress may be a less robust correlate of susceptibility to and use of e-cigarettes and marijuana because relatively low levels of CHD-related stress are experienced during adolescence (Jackson et al., 2017). Thus, it is possible that disease-related stress may emerge as a correlate of e-cigarette and marijuana use as CHD survivors transition into adulthood and potentially experience greater disease burden. Finally, although no statistically significant associations were observed, there was a trend ($p = .078$) toward an association between disease-related stress and ever use of marijuana. The study sample size may have been insufficient to detect the smaller associations between ever use and disease-related stress (e-cigarettes: OR = 1.48; marijuana: OR = 1.66) compared to those observed for ever use and global stress (e-cigarettes: OR = 2.65; marijuana: OR = 2.31).

Although both global and disease-related stress were higher among female adolescents, the associations between stress and susceptibility to e-cigarettes and marijuana did not differ by gender. This finding indicates that stress is an important correlate of susceptibility to e-cigarettes and marijuana for both male and female adolescents. In contrast, other research has found gender differences in the associations between stress and e-cigarette use (Leventhal et al., 2017) and depressive symptoms and marijuana use (Assari, Mistry, Caldwell, et al., 2018). It is possible that gender differences are not present among adolescents who are at risk for using e-cigarettes or marijuana but rather emerge during the progression from susceptibility to onset of use, potentially because of gender differences in coping (Graves et al., 2021).

Limitations

The present study contributes novel information about e-cigarettes and marijuana among adolescents with CHD. However, several limitations must be considered. First, the cross-sectional design and lack of a comparison group of healthy peers prevent inferences about the temporal association between stress and susceptibility to and use of e-cigarettes and marijuana, as well as inferences regarding the relative strength of the association between stress and e-cigarettes and marijuana among adolescents with CHD compared to adolescents without CHD. For example, longitudinal research with a comparison group will facilitate the examination of increased stress as a possible mechanism of e-cigarette and marijuana susceptibility and use among adolescents with CHD compared to those without CHD. Second, susceptibility and ever use were determined via self-report and could be impacted by social desirability, particularly given that the study was conducted in a medical setting, possibly underestimating the number of adolescents with CHD who are at risk for or who engage in these behaviors. Objective measurement of e-cigarette and marijuana use via biomarkers may assist with accurately identifying the prevalence of e-cigarette and marijuana use. Third, participants were recruited from adolescents actively engaged in cardiology follow-up and may differ from adolescents with care lapses in terms of risk for and use of e-cigarettes and marijuana, as well as global and disease-related stress. Future research should employ methods to recruit participants who are not actively engaged in follow-up care to increase the representativeness of study sample. This strategy will enhance the generalizability of the findings and facilitate more reliable comparisons with healthy adolescents. In addition, adolescents with complex CHD were less likely to participate, which also limits the generalizability of the findings. Further, while a high recruitment rate was achieved, the overall sample size may have been insufficient to detect smaller but meaningful associations for ever use. Finally, adolescents' experiences of racism and discrimination were not assessed. This limitation is notable given that perceived racial discrimination impacts adolescent marijuana (Assari et al., 2019) and cigarette (Assari, Mistry, & Caldwell, 2018) use. Additional work is needed to delineate the relationships between racism and discrimination and e-cigarettes, marijuana, and stress among adolescents with CHD.

Conclusions

In summary, susceptibility to e-cigarettes and marijuana is common among adolescents with CHD, potentially compromising their cardiovascular and cognitive health. Importantly, the extent of these risky behaviors may be underestimated during standard clinical care, as few patient medical records are concordant with adolescent self-report of use of tobacco/e-cigarettes and marijuana (Masonbrink et al., 2021). Furthermore, many pediatric cardiologists do not routinely discuss tobacco use with patients and families (Lentzner et al., 2003). Cardiology providers may benefit from training in the Act-Counsel-Treat (American Academy of Pediatrics, n.d.) or Screening, Brief, Intervention, and Referral to Treatment (Babor et al, 2007) models to improve accurate assessment of e-

cigarette and marijuana use and identify adolescents who may benefit from prevention programming.

The present findings also imply that global stress, in particular, may be a viable target for reducing susceptibility to e-cigarettes and marijuana among adolescents with CHD regardless of gender; however, additional work is needed to determine if stress has a differential impact on use according to gender. Mindfulness-based approaches to stress reduction have shown promise for adolescents with CHD (Freedenberg et al., 2017) and for reducing marijuana use (De Dios et al., 2012). In addition, such stress reduction approaches may have the added benefit of positively impacting other physical health outcomes, such as blood pressure (Scott-Sheldon et al., 2020), and mental health outcomes, such as depression (Pinhas-Hamiel & Hamiel, 2020).

Thus, future research should develop and test prevention interventions, emphasizing stress reduction, to reduce e-cigarette and marijuana susceptibility and use. In addition, future work is needed to directly compare adolescents with CHD to both healthy adolescents and adolescents with other medical complexities to identify potential differences in mechanisms of e-cigarette and marijuana susceptibility and use. Such work may help delineate what intervention components can be broadly applied to all adolescents versus those that require tailoring for specific populations. Disease-related stress should be examined as a correlate or possible mechanism of e-cigarette and marijuana use as adolescents age into young adulthood and take more responsibility for disease self-management, possibly identifying unique opportunities for intervention for those with CHD.

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