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Parent, sibling and peer influences on smoking initiation, regular smoking and nicotine dependence. Results from a genetically informative design

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Abstract

We sought to determine whether parenting, sibling and peer influences are associated with offspring ever smoking, regular smoking and nicotine dependence (ND) after controlling for familial factors. We used a twin-family design and data from structured diagnostic surveys of 1,919 biological offspring (age 12–32 years), 1,107 twin fathers, and 1,023 mothers. Offspring were classified into one of four familial risk groups based on twin fathers' and their co-twins' history of DSM-III-R nicotine dependence. Multivariate multinomial logistic regression was used to model familial risk, paternal and maternal parenting behavior and substance use, sibling substance use, and friend and school peer smoking, alcohol and drug use. Ever smoking was associated with increasing offspring age, white race, high maternal pressure to succeed in school, sibling drug use, and friend smoking, alcohol and drug use. Offspring regular smoking was associated with these same factors with additional contribution from maternal ND. Offspring ND was associated with increasing offspring age, male gender, biological parents divorce, high genetic risk from father and mother ND, maternal problem drinking, maternal rule inconsistency and sibling drug use, and friend smoking, alcohol and drug use. Friend smoking had the largest magnitude of association with offspring smoking. This effect remains after accounting for familial liability and numerous parent and sibling level effects. Smoking interventions may have greatest

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impact by targeting smoking prevention among peer groups in adolescent and young adult populations.

Keywords

smoking; nicotine dependence; peers; gene and environment

1. Background

It is well established that genetic factors play an important role in smoking milestones from initiation to nicotine dependence (ND). Genes, shared and unique environmental factors contribute to smoking initiation (ever trying cigarettes) and regular smoking (i.e. self report of ever being a smoker, ever smoking 100 cigarettes) (Madden et al. 2006; True et al. 1997;), while persistent smoking and ND appear to be due to genetic and unique environmental factors (Madden et al. 2006; True et al. 1997; True et al. 1999). The estimates of the genetic contribution to regular smoking range between 58–74% (Heath & Martin 1993; Madden et al. 2006; Pergadia et al. 2006a; Pergadia et al. 2006b; True et al. 1997; True et al. 1999). Genetic factors have been found to account for 33–70% of the variance in risk for developing ND (Heath & Madden 1995; Heath & Martin 1993; Kendler et al. 1999; Lessov et al. 2004; Maes et al. 2004). Genetically-informative studies have not included measured environmental influences in models to determine the nature of the environmental factors that account for the remaining variance in risk for reaching these smoking milestones. Examples of measured environmental influences shown to contribute to smoking initiation, persistence and dependence include parent-child conflict and parent-child closeness, sibling, peer and friend smoking and substance use. Increased risk of smoking initiation and regular smoking are also associated with parenting style (Duncan et al. 1998; Huver et al. 2007). Older sibling smoking and drug use is a strong predictor of cigarette use by other offspring (Mayhew, Flay & Mott 2000). Numerous studies have implicated the strong effect of friend and perceived peer smoking (Castrucci et al. 2002) as predictors of young adult and adolescent smoking habits. However it is not known if peer smoking and other family and non-family environmental variables remain significant predictors of adolescent and young adult smoking after controlling for familial vulnerability.

D'Onofrio and colleagues (2003) demonstrated that the offspring of twins design can address limitations of the classical twin design and can be used to quantify processes underlying intergenerational transmission of disease. The classic twin design may overestimate the variance due to genes because gene x shared environment interactions are attributed to additive genetic variance unless specifically modeled (Heath and Nelson, 2002; Jacob et al., 2001). If there is not a main effect of the shared environment, it may appear that family resemblance is completely determined by genetic transmission. Also, in the case when a main effect of the shared environment is masked by genetic dominance (non-additive genetic factors) it may appear that family resemblance is determined only by genetic transmission.

Using an offspring of twins design identical to the present study design we have modeled the family and non-family environmental contributions to cannabis abuse/dependence while accounting for the heritability of this disorder (Scherrer et al. 2008). The present study utilizes the offspring of twins design to: 1) test for bivariate associations between parent, sibling and peer level variables and offspring smoking initiation, regular smoking and ND and 2) determine which family and non-family environmental contributions to smoking initiation, regular smoking and ND remain significant after controlling for familial vulnerability. We hypothesize that parent, sibling and peer influences will be significant

predictors of offspring smoking outcomes even after adjusting for variance due to familial factors.

2. Methods

2.1. Subjects

Participants were offspring of male twins from the Vietnam Era Twin Registry (VETR), which is a national registry of monozygotic (MZ) and dizygotic (DZ) twin pairs who served in the military during the Vietnam Era (1965–1975). Construction of the registry and method of determining zygosity have been previously reported (Eisen et al. 1987; Eisen et al. 1989; Henderson et al. 1990). Data used to select families for the present project came from 1987 and 1992 surveys of the twin fathers. A mailed questionnaire sent to the twins in 1987 was used to verify family composition including number and birth dates of their children (Henderson et al. 1990). The twin fathers' DSM-III-R nicotine dependence and other psychiatric diagnoses were obtained from responses to a 1992 computer assisted telephone administration of the Diagnostic Interview Schedule (Robins LN et al. 1988; Robins, et al. 1981)

The present study involved analyses of data from twin fathers and from diagnostic telephone interviews (Bucholz et al. 1994) with biological mothers and their offspring in two complementary offspring-of-twins projects conducted from 2001–2004. All offspring were born to twin fathers from the VETR. Data from a 1992 interview with the twin fathers (Tsuang et al 1996) permitted classifying twin fathers as alcohol dependent, drug dependent or both. From these data, families in the offspring of twins projects were selected if the twin fathers were concordant or discordant for alcohol dependence (Project 1), and in Project 2 families were selected if twin fathers were concordant or discordant for illicit drug dependence (DD). Both studies included unaffected twin pairs and their families as controls. We combined data from both offspring of twins projects to increase our total sample size. This was possible because both studies used similar survey instruments. The present data set was created by using data from the most recent interview if subjects had participated in both Projects 1 and 2. In the present study we analyzed data from 1,107 fathers, 1,919 offspring between ages 12–32 and 1,023 biological mothers (2.9% rearing only/non-biological) that participated in either Project 1 or Project 2 (described above).

Experienced staff from the Institute for Survey Research (ISR) at Temple University conducted data collection. Interviewers were blind to the substance use history of respondents and gave equal effort to recruitment of all respondents. All participants gave verbal consent prior to being interviewed, as approved by the Institutional Review Board at the participating institutions. Parents provided written consent for their minor aged offspring to be interviewed.

Analyses of non-response indicated no evidence for differences in participation for fathers with and without a substance use disorder (alcoholism or drug dependence) and their offspring (Duncan et al. 2008; Scherrer et al. 2004). Descriptions of survey contents and response rates have been previously published (Duncan et al. 2008; Scherrer et al. 2004), and a brief description is presented here. Project 1 resulted in the following response rates: of the 1,464 targeted twin fathers, 1,213 (83%) participated in the study as did 862 participating mothers (67% of 1,282 eligible) and 1,270 offspring 12–25 years of age (85.4% of 1,487 eligible) participated in the 2001 survey. In Project 2, of eligible twin fathers, 725 (81% of the 895 eligible) were interviewed, 427 (72.8% of the 601 eligible) mothers were interviewed and 839 offspring aged 12–32 (88% of the 950 eligible) participated in the 2003–2004 interviews.

2.2. Variable definitions

2.2.1. Offspring Smoking Variables—Ever smoking cigarettes was defined by a positive response to the question, 'did you ever try smoking cigarettes'. Regular smoking was defined as having smoked 21 or more cigarettes over the lifetime and smoking three or more times per week for a minimum of three weeks. This intensity of smoking is associated with loss of control over cigarettes, ND and withdrawal in young smokers (DiFranza et al. 2007) and was appropriate in this young cohort where 22% were under age 18. The Fagerstrom Test for Nicotine Dependence (FTND) was used to define ND (Fagerstrom 1978; Heatherton et al. 1991) for all offspring who were regular smokers. Offspring with a value of 4 or greater on the FTND were defined as ND. From these data we created a four level categorical variable for offspring smoking: never smoker, ever smoked, regular smoker and ND.

2.2.2. The 4-Group Design—A 4-Group design variable was created to detect the genetic and environmental risk for offspring smoking outcomes based on the father's and father's co-twin DSM-III-R ND status which was obtained as part of the father's 1992 interview. Group 1 was comprised of offspring whose fathers had a lifetime diagnosis of DSM-III-R ND regardless of co-twins ND status and zygosity (high-genetic, high-environment (HG-HE) risk group). These offspring are posited to be at high genetic risk because of their father's history of ND and at high environmental risk by virtue of being reared by a ND father. Group 2 was comprised of offspring whose fathers did not have ND but the fathers' MZ co-twins (i.e., the offspring's uncle) met ND criteria, (high-genetic, low-environment (HG-LE) risk group). Group 3 was comprised of offspring whose fathers did not have ND but their DZ co-twins (i.e., offspring's uncle), met ND criteria (medium-genetic, low-environment (MG-LE) risk group). Offspring in the HG-LE group (group 2) are posited to have been at high genetic risk because their fathers share 100% of their genes with their ND cotwin, whereas those in the MG-LE (group 3) are at medium genetic risk because their fathers share on average 50% of their genetic material with their ND DZ cotwin. Both groups 2 and 3 offspring are posited to be at low family environmental risk because they were reared by an unaffected father. Finally, group 4 was comprised of offspring whose fathers and father's cotwin (MZ and DZ) did not meet criteria for ND and are theorized to be at low-genetic, low-environment (LG-LE) risk.

2.2.3. Sampling Design Variable—Because the samples for the current project were from two separate offspring of twins design studies, the sampling design variables for these projects were included in all analyses. The sampling design variable was a 7-level variable based on father and co-twins alcohol dependence (AD) and drug dependence (DD) status and zygosity. Level 1 consisted of offspring born to fathers with DD with and without AD. Father DD was highly comorbid with AD and therefore considered together in DD fathers. Level 2 offspring were born to unaffected MZ twins whose co-twin had DD with and without AD. Level 3 offspring were born to unaffected DZ twin fathers whose co-twin had DD with and without AD. Level 4 offspring were born to fathers with AD. Level 5 offspring had unaffected MZ twin fathers whose co-twin had AD. Level 6 offspring had unaffected DZ twin fathers whose co-twin had AD, and Level 7 offspring were born to MZ and DZ twins without DD and AD.

2.2.4. Covariates

Maternal Nicotine Dependence: Maternal contribution to the familial risk for smoking was modeled using the Heaviness of Smoking Index (HSI) defined by time to 1st cigarette upon waking and number of cigarettes smoked per day when smoking the most (Heatherton et al. 1989). Based on evidence that HSI scores of 4 or greater indicate high ND, (Diaz et al. 2005; Heatherton et al. 1989), and consideration of the distribution of HSI scores, we

created a dichotomized HSI score so that values of 1–2 defined low and values 3 defined medium to severe ND mothers. Lifetime never smokers were the reference group.

Sociodemographic variables included offspring age, gender, paternal race (white vs. non-white), paternal and maternal education and offspring report of biological father-mother marital status (married vs. divorced, separated, widowed, never married). We did not include the offspring's own education in regression models because it was dependent upon offspring age. Instead we modeled the parents' educational attainment.

Offspring perception of parental behaviors: Offspring reported on perceived parental problem drinking with interview items derived from the Family History of Alcoholism Module (FHAM) a reliable instrument utilized in the Collaborative Study on the Genetics of Alcohol (COGA) project (Rice et al. 1995). Offspring reporting that they thought their mother or father were ever excessive drinkers or that drinking ever caused their mother or father to have problems with health, school, family, police or other problems were coded as having a parent who was a problem/excessive drinker.

As previously described in our analyses of environmental risk factors for cannabis abuse/dependence (Scherrer et al. 2008), data regarding parenting, early rearing environment and quality of relationships were obtained by the offspring's report to several questions based on Sarason and colleagues' (1991) constructs for perceived support in social relationships and from Robins and colleagues' (1985) scale for assessing early home environmental correlates of psychopathology. Offspring were asked separately about mothers' and fathers' strictness, rule consistency, closeness and pressure to perform well in school for when they were 6–13 years of age. Strictness was measured on a 5-point scale ranging from a lot more (compared to other parents) to a lot less strict. Due to the small number of subjects at the ends of the scale, we modeled strictness as a 3 level variable, a lot more/little more; same; a little less/a lot less. Rule consistency was measured with a binary response to the question, 'Was your mother/father pretty consistent about rules or would she/he insist upon a rule one day and forget about it the next?' Closeness was measured on a 4-point scale ranging from very close, somewhat close, not very close, to not at all close. Because few respondents reported that they were not at all close to their mother/father, we modeled closeness as a 3-level variable; very close, somewhat close and not very/not at all close.

Offspring perception of sibling behaviors: Offspring reported on all siblings independent of whether the sibling participated in the study, (65% had one or more siblings participating in the survey). Using the excessive and problem use questions from the FHAM, offspring who reported siblings were ever excessive drinkers or that drinking ever caused their siblings problems with health, school, family, police or other problems were coded as having a sibling who was a problem/excessive drinker. Similarly, offspring reports of sibling use of marijuana, cocaine, stimulants, opiates, hallucinogens, PCP, sedatives, solvents or inhalants were used to code sibling drug use status.

Sibling relationships were measured by offspring reports on how much they could discuss worries with any sibling, how much they thought any sibling would help with problems and how much they thought a sibling would understand them. Responses to each question were on a 4 level scale ranging from 'a lot' to 'not at all'. Because the sibling support variables were highly correlated, we created a 10 level ordinal sibling support variable by summing the responses to each 4 point scale which produced a range of values from 3 to 12 that we re-scaled to values 1 to 10. The cronbach alpha for this measure was 0.86 and we have used this scaling procedure for previous studies of sibling support and cannabis/abuse dependence (Scherrer et al. 2008).

Offspring perception of peer behaviors included perceived smoking, alcohol and drug use among current same sex and opposite sex friends. For the current friends question, offspring reported the number of current male/female friends that used drugs such as marijuana, the number that used alcohol at least once a week, and the number that smoked cigarettes by answers to the following questions: 1) In your opinion, how many of your friends have used alcohol?; 2) how many have used marijuana?; 3)... how many smoke cigarettes?.

Subjects also answered a separate series of questions about substance use among students in their high school who were in the same grade, or if the offspring were high school graduates, about their peers during the 12th grade. For the school peer questions, offspring were asked how many students used any drugs including marijuana, how many used alcohol and how many smoked cigarettes by answers to the following questions: How many students in your high school who are/were in the same grade as you ... 1) used any drugs including marijuana?, `...used alcohol?`, `...smoked cigarettes`.

Response options for both the friends and school peer questions were on a 7 point scale from `none`, `just a few`, `a quarter`, `half`, `three-quarters`, `almost all` to `all`. We collapsed across categories to create a 3-level variable for friends use as none, a few and a quarter or more. Peer use was also modeled as a 3 level variable: none/a few, quarter to one-half and one-half or more.

2.3.1. Analyses—Descriptive analyses of all independent and outcome variables are expressed as percentages for categorical variables. Cross-tabulations and chi-square tests of significance were used to examine bivariate associations among each predictor variable and offspring ever trying a cigarette, offspring regular smoking and offspring ND.

Prior to adopting the multinomial logistic regression model (i.e., generalized logistic regression model); each logistic regression model with the 4-level offspring smoking outcome was tested to determine if the assumption of proportional odds was met (i.e., ordinal pattern of the 4-level smoking outcome variable). The test yielded a significant violation of the proportional odds model ($p < 0.05$), so the multinomial logistic regression model was adopted for all analyses.

Analyses began by testing if parent, sibling and peer variables had a bivariate association with the 4 level offspring smoking outcome. All variables significant at the bivariate level were included in the multivariate multinomial logistic regression models. All models controlled for genetic vulnerability for ND imparted from parental smoking. This was accomplished by modeling the effect of the 4-Group design variable described in section 2.2.2. This variable was forced into the model as a dummy variable representing varying degrees of genetic and environmental vulnerability for nicotine dependence. However, we note that the maternal nicotine dependence variable was treated as a covariate and not a measure of genetic and environmental vulnerability because mothers were not twins and thus varying levels of genetic vs. environmental influence could not be established for their influence on offspring smoking behaviors.

Inspection of the full tetrachoric correlation matrix revealed sibling problem alcohol use and sibling drug use were collinear as were friend alcohol and drug use and school peer alcohol and drug use (polychoric correlations > 0.65). Thus we created combined sibling alcohol/drug, friend alcohol/drug use and school peer alcohol/drug use variables. The full correlation matrix is available upon request. All analyses were computed using the SURVEYLOGISTIC procedure in SAS v.9.0 which adjusts error variance in non-independent observations.

3.0. Results

Descriptive

As shown in Table 1, offspring age, white race, maternal education and parents intact marital status were associated with ever smoking, regular smoking and ND relative to never smoking. Male gender was associated with lower prevalence of regular smoking but a higher prevalence of ever smoking and ND.

Table 2 displays the association of predictor variables among offspring by smoking outcomes. The paternal 4-group design variable, maternal 'HSI' were positively ($p < 0.05$) associated with offspring smoking outcomes relative to never smoking. Group 1 offspring, those at high genetic and high environmental risk for ND, were more often ever smokers, regular smokers and ND compared to being never smokers. Likewise, offspring of mothers with ND (i.e. high heavy smoking index) were also more likely to be ever, regular and ND smokers.

As shown in Table 3, with the exception of maternal strictness and paternal pressure to do well in school, all parental level variables were associated with the smoking outcomes relative to never smoking. Excessive parental drinking was associated with ever, regular and ND smoking. Less paternal strictness was associated with ever, regular and ND smoking. Similar patterns were observed for parental rule inconsistency. Relatively more offspring were ever smokers, regular smokers and ND as compared to never smokers if they reported not being close to mother or father. Last, reporting little pressure to do well in school was associated with a higher proportion of smoking outcomes relative to never smoking.

The distribution of offspring perceptions of sibling behaviors is shown in Table 4. As compared to never smoking offspring were more likely to have ever tried cigarettes, been regular smokers and ND if they perceived their sibling as ever having been a problem/excessive drinker or perceived siblings used illicit drugs.

Multinomial Logistic Regression Results

As shown in Table 5, relative to never smoking, offspring perceptions of current friends smoking and drinking was associated with ever smoking, regular smoking and ND. Older respondents were significantly more likely to be ever smokers (OR=1.10; 95%CI: 1.06–1.15) regular smokers (OR=1.15; 95%CI: 1.10–1.20) and nicotine-dependent smokers (OR=1.20; 95%CI: 1.14–1.26). Compared to never smokers, regular smokers (OR=2.31; 95%CI: 1.08–4.94) were more likely to be white and ND offspring were more likely to have divorced biological parents (OR=2.20; 95%CI: 1.42–3.40).

Offspring ever smokers were not at increased genetic risk for smoking relative to never smokers. However, offspring regular smoking was associated with maternal low HSI (OR=1.70; 95%CI: 1.08–2.67) and offspring ND was associated with having a father who was ND and mother with high HSI (OR=2.13; 95%CI: 1.25–3.63; and OR=1.80; 95%CI: 1.10–2.94, respectively).

Among perceived parental behaviors, maternal problem drinking was associated with offspring ND (OR=2.30; 95%CI: 1.19–4.46) and greater paternal strictness was associated with both offspring ever smoking (OR=1.41; 95%CI: 1.03–1.95) and regular smoking (OR=1.54; 95%CI: 1.02–2.32).

Perceived sibling problem substance use (problem alcohol and/or illicit drug use) was more common among offspring ever smokers (OR=1.45; 95%CI: 1.10–1.94) and regular smokers

(OR=2.04; 95%CI:1.41–2.95) and among offspring with ND (OR=1.75; 95%CI:1.19–2.57) as compared to offspring never smokers.

Offspring ever smoking (OR=1.78; 95%CI:1.31–2.39), regular smoking (OR=3.08; 95%CI: 2.03–4.68) and offspring ND (OR=5.04; 95%CI: 3.05–8.33) were all significantly associated with perception of the number of friends who smoke. The magnitude of association between friend smoking and offspring ever smoking, regular smoking and ND increased as the number of perceived friends who smoked increased. Of note, if offspring perceived a quarter or more of their friends smoked the odds of ND was 32.0 (95%CI:18.1–56.6) times greater than perceiving no friends smoked.

Friends' alcohol and or illicit drug use was associated with offspring ever smoking, regular smoking and ND criteria (OR range 2.01–3.87). As compared to never smokers, offspring with ND were more likely to report one-half or more of their school peers smoked (OR=2.11; 95%CI:1.08–4.13). Perceived student alcohol and drug use was not associated with offspring smoking outcomes.

The sampling design variable and non-response from mothers were not associated with offspring smoking outcomes in the multivariate analyses.

4.0 Discussion

Results of multinomial logistic regression using 1,919 offspring at varying levels of genetic vulnerability for ND suggested ever smoking was associated with increasing offspring age, white race, high maternal pressure to succeed in school, sibling drug use, and friend smoking, alcohol and drug use. Offspring regular smoking was associated with these same factors with additional contribution from maternal ND. Offspring ND was associated with increasing offspring age, male gender, biological parents divorce, high genetic risk from father and mother ND, maternal problem drinking, maternal rule inconsistency and sibling drug use, and friend smoking, alcohol and drug use. To our knowledge these findings are novel in that family and non-family measured environmental factors contribute to offspring smoking outcomes after controlling for familial vulnerability.

For all outcomes the largest magnitude of influence came from friend smoking, but we are unable to determine if this is due to peer influence or peer selection (Madden et al. 2002). In a parallel study of offspring of drug dependent fathers, we found the largest risk for cannabis dependence was perceived friend cannabis use but peer smoking was not associated with cannabis abuse/dependence. Taken together, these two studies suggest some specificity for the environmental contribution to offspring substance use. Further research is warranted to determine the relative magnitude of peer drinking on offspring alcoholism.

Many of our observations are consistent with other large cohort studies. Increasing age is associated with increasing smoking and ND (Hu, Davies & Kandel 2004) in adolescents and young adults. And our finding for an association between white race and regular smoking is consistent with previous studies in the United States (Park, Weaver & Romer 2009). Previous studies have demonstrated peer smoking is significantly associated ever smoking (Hu, Davies & Kandel 2004), transitions to daily smoking (Bricker et al. 2007) and with developing ND (Hu, Davies & Kandel 2004; Kandel et al. 2007). Our study is unique in demonstrating the significance of peer influences after accounting for familial vulnerability for ND and measured environmental influences. Similarly unique is the finding that sibling substance use remained significantly associated with all offspring outcomes. This is consistent with other population based cohorts (Boyle et al. 2001) but we believe our analysis is the first to demonstrate a contribution from sibling smoking even after accounting for degree of genetic and environmental risk for ND from the parent generation.

We found paternal alcoholism and illicit drug dependence did not predict offspring smoking initiation or regular smoking, but high familial risk for ND was associated with offspring ND. This finding extends our previous analyses demonstrating the specificity of the inter-generational transmission of alcohol dependence and nicotine dependence in a subset of offspring of alcoholic twins (Volk et al. 2007). Our current results are not completely consistent with classical twin models of smoking outcomes in which genetic factors have been shown to contribute to tobacco use, regular smoking and ND. For example, Maes et al. (2004) reported high heritability for initiation of tobacco use, regular smoking, and ND (75%, 80%, and 62%, respectively) and substantial genetic correlations between phenotypes, but found that over one-third of genetic liability was specific to ND (Maes et al. 2004). Investigations of common heritable influences on initiation and persistence of smoking (Madden et al. 2006; True et al. 1997; True et al. 1999) and on initiation and ND (Fagerstrom 1978) are mostly consistent in that genetic factors for regular smoking are not completely accounted for by the genetic factors contributing to smoking initiation (True et al. 1997; Heath & Madden 1995). We speculate that the variance attributed to genetic factors in the classical twin design are partly associated with sibling substance use and peer substance use which are modeled in the present paper but not accounted for in classical twin studies.

The absence of a significant association between parental closeness and smoking is consistent with other multivariate analysis of parent and sibling influences on smoking (Picotte et al. 2006)

4.1. Strengths

A principal strength of the present work is the use of the twin-offspring design which permits a sensitive test for measured environmental influences while accounting for genetic vulnerability due to parental ND. Additional strengths include the large sample size and non-clinical sample that enhance generalizability while avoiding bias inherent to clinical samples. The structured method of data collection reduces interviewer bias. Last the large age range of the offspring permitted modeling the major smoking milestones in adolescents and young adults. We computed post-hoc sensitivity analysis using data only on offspring 18 years and older and can conclude that point estimates were not significantly different before and after limiting the cohort to these older aged offspring.

4.2. Limitations

Sample size limitations may have reduced our statistical power to detect differences in the risk for smoking outcomes between Group 2 (HG-HE) and Group 3 (MG-LE) effects. Power to detect differences between these groups was 30%. However, we are able to conclude that high genetic and high environment as compared to low genetic and low environmental risk is associated with offspring ND, and we can conclude that environmental factors contribute to offspring smoking outcomes after accounting for familial vulnerability (i.e. Group 4 vs. 1).

It is not possible to measure all environmental influences on offspring. We lacked data on offspring perception of peer smoking and lacked self reported measures from siblings on smoking, alcohol and drug use. Expansion of the shared environment assessment may reveal key parent, sibling and peer level variables that have not been adequately measured. Longitudinal data will help clarify the direction of effect for peer substance use. Follow-up is necessary to collect more detailed assessment of the parent-offspring environment, to expand upon sibling substance use and drug problems and the impact of older as compared to younger siblings on offspring smoking and to model trajectories related to life events associated with adulthood.

Because DSM-III-R criteria ND is weakly correlated with FTND it is possible that our results have underestimated the genetic contribution from paternal ND to offspring ND and overestimated the environmental contribution to offspring ND. Since offspring who smoke are more likely to perceive peers smoke it is possible that we overestimate the environmental contribution from peer smoking to offspring smoking.

Last, because of the ubiquitous exposure to tobacco in the military the present cohort may be more exposed to tobacco than those found in offspring of civilian populations.

Conclusions—Parent, sibling and peer level variables contribute to offspring ever smoking, regular smoking and ND. Even after controlling for familial vulnerability to ND, environmental contributions to smoking remain significant.

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HIGHLIGHTS

- Parenting contributes to smoking
- Peer smoking contributes to offspring smoking
- Effects remain after controlling for familial risk

Table 1

Distribution (%) of sociodemographic variables within offspring smoking variables.

	Offspring smoking variables:			
	Never tried cigarette	Ever tried cigarette	Regular smoking	Nicotine Dependence ¹⁾
	N=628	N=667	N=310	N=314
Offspring mean ($\pm$ S.E.) age	19.6 $\pm$ 0.22	21.9 $\pm$ 0.18	22.5 $\pm$ 0.20	23.0 $\pm$ 0.23 **
white	89.6	94.3	96.0	96.5 **
Male	46.8	50.5	43.9	58.0 **
Father education > High School	63.9	62.7	66.0	64.1
Mother education > High School	66.7	62.2	66.5	53.8 **
Parents married	81.1	74.6	71.5	56.4 **

p<0.05,

¹⁾ The Fagerstrom Test for Nicotine Dependence (FTND) was used to define nicotine dependence Chisq:**
p<0.01

Table 2

Distribution (%) of parent risk factors within offspring smoking variables.

	Offspring smoking variables:			
	Never tried cigarette	Ever tried cigarette	Regular smoking	Nicotine Dependence ²⁾
	N=628	N=667	N=310	N=314
<u>familial vulnerability</u>				
4-group design: ¹⁾				
GRP 1 (HG, HE)	44.0	49.3	55.5	69.1 **
GRP 2 (HG, LE)	8.1	6.9	9.4	9.9
GRP 3 (MG, LE)	12.1	9.6	9.7	6.7
GRP 4 (LE, LE)	35.8	34.2	25.5	14.3
Maternal Heavy Smoking Index ⁷ :				
Lifetime non-smoker	64.8	58.3	51.8	48.9 **
Low	16.9	20.1	23.3	16.0
High	18.3	21.6	24.9	35.1

Chisq:

**
p<0.01

¹⁾ 4-Group design: Group 1 - Offspring at high genetic (HG) and high environmental (HE) risk because fathers are MZ and DZ twins with DSM-III-R ND, Group 2- Offspring at high genetic (HG) and low environmental (LE) risk because fathers are unaffected MZ twins whose co-twin has DSM-III-R ND, Group 3- Offspring at medium genetic (MG) and LE risk because fathers are unaffected DZ twins whose co-twin has DSM-III-R ND, Group 4- offspring at low genetic and LE because fathers are unaffected ND MZ and DZ control pairs.

²⁾ The Fagerstrom Test for Nicotine Dependence (FTND) was used to define nicotine dependence

Table 3

Distribution (%) of offspring perceived parent behaviors within offspring smoking variables.

	Offspring smoking variables:			
	Never tried cigarette	Ever tried cigarette	Regular smoking	Nicotine Dependence ¹⁾
	N=628	N=667	N=310	N=314
Mother problem/excessive drinker:	4.3	5.1	7.4	13.7**
Father problem/excessive drinker:	15.0	23.2	24.8	33.8**
Mother strictness:				
Little less/lot less	18.3	16.7	23.6	24.4
Same	41.3	41.6	38.2	35.7
A lot more/little more	40.4	41.7	38.2	39.9
Father strictness:				
Little less/lot less	22.0	24.3	24.0	29.1*
Same	42.4	35.5	34.7	33.3
A lot more/little more	35.5	40.2	41.2	37.5
Mother not consistent about rules	9.0	13.2	19.0	25.7**
Father not consistent about rules	9.3	15.4	14.8	19.4**
Mother closeness:				
Very close	76.0	68.7	64.8	62.7**
Somewhat close	20.5	26.2	27.7	28.7
Not very/ not at all close	3.5	5.1	7.4	8.6
Father closeness:				
Very close	57.1	51.0	46.1	43.9**
Somewhat close	34.9	38.9	37.3	36.9
Not very/ not at all close	8.0	10.2	16.6	19.2
Mother pressure to do well in school:				
A lot	30.9	36.6	30.3	31.1*
Some	46.3	45.9	55.8	48.7
A little	16.0	12.5	8.4	14.7
None	6.9	5.0	5.5	5.5
Father pressure to do well in school:				
A lot	26.7	31.3	31.2	30.3
Some	46.6	42.7	48.2	46.1
A little	18.4	20.2	17.1	17.4
None	9.3	5.9	3.6	6.1

¹⁾ The Fagerstrom Test for Nicotine Dependence (FTND) was used to define nicotine dependence Chisq:

* p<0.05,

** p<0.01

Table 4

Distribution (%) of offspring perception of sibling and peer behaviors within offspring smoking variables.

	Offspring smoking variables:			
	Never tried cigarette	Ever tried cigarette	Regular smoking	Nicotine Dependence ¹⁾
	N=628	N=667	N=310	N=314
no full biological siblings	87.9	90.1	88.4	85.0
any full biological siblings	12.1	9.9	11.6	15.0
any sibling problem/excessive drinker:	16.4	21.9	20.3	25.2**
any sibling use illicit drugs				
none	74.8	53.9	41.5	44.8**
cannabis only	13.2	26.2	27.9	21.4
cannabis and other drugs	12.0	19.9	30.6	33.8
sibling support mean ($\pm$ S.E.)	6.8 $\pm$ 0.14	7.1 $\pm$ 0.13	6.8 $\pm$ 0.20	6.4 $\pm$ 0.21
Current friends smoke:				
none	71.1	42.9	22.3	11.3**
a few	23.4	36.1	34.0	27.4
a quarter or more	6.6	21.0	43.7	61.3
Current friends drink at least 1/week:				
none	55.1	21.1	13.6	15.8**
a few	24.8	33.9	32.4	21.0
quarter or more	20.1	45.0	54.1	63.2
Current friends use drugs:				
none	59.7	27.0	11.7	9.4**
a few	27.0	40.2	36.0	26.5
quarter or more	13.3	32.8	52.3	64.2
school peer smoking:				
none/ a few	31.7	18.8	12.3	11.7**
quarter to one-half	55.9	61.9	66.3	60.8
one-half or more	12.4	19.4	21.4	27.5
school peer drinking:				
none/ a few	25.9	11.4	6.2	7.8**
quarter to one-half	44.3	44.0	39.2	36.6
one-half or more	29.8	44.6	54.7	55.7
school peer drug use:				
none/ a few	44.4	31.5	24.6	18.8**
quarter to one-half	46.6	53.3	50.2	53.1
one-half or more	9.0	15.2	25.2	28.2

*p<0.05,

¹⁾The Fagerstrom Test for Nicotine Dependence (FTND) was used to define nicotine dependence Chisq:

**
p<0.01

Table 5

Multinomial logistic regression modeling results showing association between parent, sibling and peer behaviors and offspring smoking variables with never smoking as the common reference.[†]

	Offspring smoking variables:		
	Ever Smoked	Regular smoker	Nicotine Dependence ¹⁾
Sociodemographic variables	OR(95%CI)	OR(95%CI)	OR(95%CI)
offspring age	1.11 (1.07–1.15)	1.17 (1.11–1.22)	1.21 (1.15–1.28)
father's self reported race: white	1.97 (1.08–3.59)	3.17 (1.33–7.53)	2.03 (0.82–5.04)
male offspring	1.11 (0.85–1.47)	0.81 (0.57–1.15)	1.54 (1.05–2.26)
mother education high school	1.15 (0.83–1.59)	0.74(0.48–1.13)	1.20 (0.76–1.88)
Parents not married	1.35 (0.95–1.91)	1.12 (0.70–1.80)	2.04 (1.29–3.20)
Father and mother self reported nicotine dependence (ND)			
father ND 4-group ²⁾ :			
ND Group1 (HG-HE)	0.85 (0.59–1.22)	1.17(0.71–1.91)	2.25 (1.28–3.95)
ND Group2 (HG-LE)	0.66 (0.37–1.18)	1.15 (0.56–2.38)	1.52 (0.67–3.45)
ND Group3 (MG-LE)	0.69 (0.41–1.16)	0.89 (0.43–1.87)	1.05 (0.47–2.33)
ND Group4 (LG-LE)	1.0	1.0	1.0
mother heavy smoking index (HSI):			
Lifetime non-smoker	1.0	1.0	1.0
Low	1.20 (0.82–1.75)	1.72 (1.07–2.75)	1.18 (0.70–2.01)
High	1.10 (0.75–1.62)	1.20 (0.75–1.93)	1.76 (1.06–2.93)
Perceived parental behaviors			
mother problem drinking	1.25 (0.68–2.28)	1.80 (0.9–3.42)	2.64 (1.38–5.05)
father problem/excessive drinker	1.18 (0.82–1.72)	1.11 (0.69–1.77)	1.25 (0.78–2.00)
father strictness: little less/lot less	0.96 (0.67–1.37)	0.78 (0.49–1.24)	0.80 (0.49–1.24)
same	1.0	1.0	1.0
a lot more/little more	1.34 (0.98–1.83)	1.37 (0.90–2.08)	1.08 (0.67–1.93)
mother not consistent about rules	1.17 (0.75–1.83)	1.57 (0.94–2.62)	1.72 (1.02–2.90)
father not consistent about rules	1.49 (0.92–2.40)	1.05 (0.59–1.87)	1.34 (0.71–2.52)
mother closeness: very close	1.27 (0.62–2.61)	1.49 (0.63–3.55)	1.10 (0.48–2.54)
somewhat close	1.32 (0.91–1.89)	1.37 (0.87–2.15)	1.50 (0.95–2.38)
not very/not at all close	1.0	1.0	1.0
father closeness: very close	0.90 (0.52–1.56)	1.56 (0.84–2.90)	1.37 (0.75–2.51)
some what close	1.05 (0.78–1.43)	1.07 (0.71–1.61)	1.13 (0.73–1.74)
not very/not at all close	1.0	1.0	1.0
Mother pressure to do well in school:			
A lot	2.24(1.23–4.10)	1.80 (0.81–3.97)	2.03 (0.85–4.83)
Some	1.86 (1.01–3.41)	2.11 (0.97–4.58)	2.29 (0.96–5.45)

	Offspring smoking variables:		
	Ever Smoked	Regular smoker	Nicotine Dependence ¹⁾
A little	1.50 (0.77–2.92)	0.84 (0.35–2.01)	1.90 (0.72–5.01)
None	1.0	1.0	1.0
Perceived sibling behaviors			
no full biological siblings	1.0	1.0	1.0
any full biological siblings	1.18 (0.74–1.88)	0.91 (0.49–1.70)	0.90 (0.50–1.62)
any sibling use illicit drugs:			
none	1.0	1.0	1.0
cannabis only	2.0 (1.37–2.92)	2.84 (1.73–4.64)	1.90 (1.10–3.30)
cannabis and other drugs	1.53 (0.99–2.34)	2.92 (1.71–4.98)	2.27 (1.27–4.05)
Perceived peer behaviors			
Current friends smoked:			
none	1.0	1.0	1.0
a few	1.54 (1.11–2.13)	2.37 (1.51–3.72)	4.34 (2.48–7.25)
a quarter or more	2.12 (1.30–3.45)	7.55 (4.22–13.50)	20.8 (10.9–39.6)
Current friends drink at least 1/week:			
none	1.0	1.0	1.0
a few	1.85 (1.30–2.62)	1.75 (1.06–2.90)	0.77 (0.44–1.35)
quarter or more	2.04 (1.32–3.13)	1.2 (0.69–2.08)	0.86 (0.46–1.59)
Current friends use drugs:			
none	1.0	1.0	1.0
a few	1.84 (1.30–2.61)	3.14 (1.86–5.30)	2.28 (1.30–3.90)
quarter or more	1.77 (1.10–2.85)	3.99 (2.12–7.52)	3.43 (1.76–6.69)
school peer smoking:			
none/ a few	1.0	1.0	1.0
quarter to one-half	1.10 (0.77–1.56)	1.25 (0.75–2.08)	1.24 (0.69–2.20)
one-half or more	1.32 (0.81–2.16)	1.16 (0.59–2.27)	1.73 (0.85–3.51)
school peer drinking:			
none/ a few	1.0	1.0	1.0
quarter to one-half	1.10 (0.71–1.71)	1.55 (0.79–3.03)	1.04 (0.51–2.11)
one-half or more	1.15 (0.70–1.90)	2.03 (0.95–4.34)	1.37 (0.65–2.88)
school peer drug use:			
none/ a few	1.0	1.0	1.0
quarter to one-half	1.0 (0.70–1.43)	0.72 (0.45–1.16)	0.95 (0.58–1.55)
one-half or more	1.26 (0.73–2.16)	1.26 (0.64–2.46)	1.45 (0.74–2.86)

¹⁾ The Fagerstrom Test for Nicotine Dependence (FTND) was used to define nicotine dependence

²⁾ 4-Group design: Group 1 - Offspring at high genetic (HG) and high environmental (HE) risk because fathers are MZ and DZ twins with DSM-III-R ND, Group 2- Offspring at high genetic (HG) and low environmental (LE) risk because fathers are unaffected MZ twins whose co-twin has

DSM-III-R ND, Group 3- Offspring at medium genetic (MG) and LE risk because fathers are unaffected DZ twins whose co-twin has DSM-III-R ND, Group 4- offspring at low genetic and LE because fathers are unaffected ND MZ and DZ control pairs.

[†] adjusted for sampling design variable: 7-level design based on father and co-twins AD and DD status and zygosity. Level 1 consisted of offspring born to fathers with drug dependence (DD) with and without alcohol dependence (AD). Level 2 offspring were born to unaffected MZ twins whose co-twin had DD with and without AD. Level 3 offspring were born to unaffected DZ twin fathers whose co-twin had DD with and without AD. Level 4 offspring were born to fathers with AD. Level 5 – offspring had unaffected MZ twin fathers whose co-twin had AD. Level 6 offspring had unaffected DZ twin fathers whose co-twin had AD, and Level 7 offspring were born to MZ and DZ twins without DD and AD.