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**The intergenerational transmission of tobacco smoking –
the role of parents' long-term smoking trajectories.**

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Abstract

Youths whose parents smoke tobacco may be at elevated risk of smoking themselves. However, the association between parental long-term smoking history and offspring regular tobacco use is not well known. Using data collected on 1121 youths (12-26 years) participating in the GAZEL Youth study, a French community-based cohort, we tested the association between parental long-term smoking trajectory and offspring regular smoking. Parental smoking trajectory over 11 years (1989-1999) was measured by yearly reports obtained from the parent. Statistical analyses controlled for youth's sex, age, alcohol use and disruptive behavioral problems, parent's sex, as well as family socioeconomic position. Overall, 27% of study youths smoked regularly. Compared to offspring of non-smokers, those of persistent smokers had twofold smoking rates (age and sex-adjusted OR: 1.91, 95% CI: 1.30-2.79, fully-adjusted OR: 1.96, 95% CI 1.31-2.93). Additionally, persistent parental smoking predicted offspring heavy smoking and early smoking initiation. Overall, maternal smoking was more strongly associated with youths' regular smoking than paternal smoking (fully-adjusted ORs: 3.12, 95% 1.58-6.16 vs. 1.47, 95% 0.87-2.49). These results suggest that efforts to decrease the burden of tobacco smoking among youths may be more efficient if focused on families rather than on individuals.

Keywords: Tobacco smoking; Adolescence; Young adulthood; Parental smoking history; Longitudinal study; Epidemiology

Tobacco smoking is the leading cause of preventable death worldwide, causing 5 million deaths each year. Alarming, smoking rates are rising and by 2030 up to 10% of deaths may be tobacco-related (Mathers and Loncar, 2006).

Smoking typically begins in adolescence; however, only a fraction of youths who experiment with cigarettes become regular smokers. Youths who smoke regularly are likely to maintain their smoking habit over time (Fagan et al., 2005; Paul et al., 2008); thus the transition between adolescence and young adulthood is a propitious period for the prevention of long-term tobacco use.

What distinguishes youths at risk of regular smoking from those that are not at risk? Prior research suggests that an important factor in the progression from tobacco experimentation to regular smoking is parental tobacco smoking (Avenevoli and Merikangas, 2003; Fagan et al., 2005; McGee et al., 2006; Paul et al., 2008). In particular, the likelihood of becoming a regular smoker may be associated with parents' long-term smoking history (Bailey et al., 1993; Bauman et al., 1990). However, to date evidence in this area is inconclusive, as studies examining the intergenerational transmission of smoking mostly used indirect measures of parental smoking obtained from one parent (reporting on both parents) or from the offspring (Bailey et al., 1993; Bauman et al., 1990; McGee et al., 2006), which may be imprecise. Attempting to address these limitations, two recent studies showed that parents' persistent smoking is associated with adolescent smoking initiation (Chassin et al., 2008; Gilman et al., 2009). However, to our knowledge, the association between parents' long-term smoking

trajectories, as reported by the parents themselves, and their offspring regular smoking has not yet been examined.

Methods

Participants come from the GAZEL Youth study, set up in 1991 to examine mental health and substance use among community-based youths in France. As previously described, participating youths were recruited via one of their parents (“reference parent”) who takes part in an ongoing epidemiological study: the GAZEL cohort (Fombonne and Vermeersch, 1997; Goldberg et al. 2007). The GAZEL Youth study sample was selected to represent the socio-demographic characteristics of French youths. At baseline, in 1991, 2582 youths aged 4-18 years were included. At follow-up, in 1999, 1268 parents (49.1%) and 1148 youths (44.5%) took part in the study. These response rates are comparable to other mental health surveys conducted in France (Alonso et al. 2004). As previously reported, follow-up response rates in the GAZEL Youth study were higher among youths who were female and younger than 18 years, as well as among those whose parents were non-smokers and held a high socioeconomic position; other socio-demographic or health characteristics were not associated with study participation (Galéra et al., 2005; Galéra et al., 2008). By design, the GAZEL cohort study includes a majority of men (73.0%), which is reflected in the GAZEL Youth Study where fathers represent 68.2% of reference parents.

The Gazel Youth study received the approval of France’s national committee for data protection (CNIL: Commission Nationale Informatique et Liberté).

Measures

Youth's tobacco smoking

Youths' tobacco smoking was ascertained by self-report in 1999. Youths who reported ever smoking a cigarette were asked at what age they had first smoked and how many cigarettes per day they smoked in the preceding 12 months.

Parental tobacco smoking

Parental tobacco smoking was assessed by yearly self-report from 1989 to 1999 (n=11) in the GAZEL study. Each year, reference parents reported whether they smoked tobacco and, if yes, the daily number of cigarettes, pipes, or cigars. We excluded from the analyses observations with fewer than 6 data points on parental smoking (n=8); among the remaining study sample, 3.5% of parents reported smoking behavior on 6-8 measurements, 4.8% on 9 measurements, 17.3% on 10 measurements, and 73.5% on all 11 measurements. This information served to construct longitudinal trajectories of parental tobacco use: no smoking (77.7% of parents), declining smoking (8.5%) or persistent smoking (13.8%). These trajectories were identified empirically using a semiparametric mixture model (Jones et al., 2001). For each tobacco smoking group, the model defined the shape of the trajectory and the proportion of parents in each group. The validity of this classification was confirmed using the Bayesian Information Criterion (BIC). Additionally, we verified that patterns of tobacco use varied across smoking trajectories: on average, parents in the 'non-smoking' group

smoked 1.2 packs of cigarettes/year and 0.6% were smokers in 1999, compared with 14.1 packs/year and 13.8% of smokers in the 'declining smoking' group and 214.0 packs/year and 80.8% of smokers in the 'persistent smoking' group.

Covariates

Familial characteristics, collected in the GAZEL study in 1989, included the reference parent's sex (female vs. male) and family income (dichotomized at the bottom third: <800 euros/month vs. $\geq$ 800 euros/month per person in the household). Youths' characteristics, assessed in the GAZEL Youth study in 1999, included youth's sex (female vs. male), age (12-15, 16-18, 19-21, 22-25 years), and regular alcohol use (<10 times vs. $\geq$ 10 times in the preceding 30 days). Youths' disruptive behavioral problems, known to predict tobacco use (Armstrong and Costello, 2002), were measured at baseline in 1991 using two subscales of the Child Behavior Checklist (CBCL) (Achenbach, 1991): rule-breaking behaviors (14 items) and aggressive behaviors (18 items). Following published guidelines, these two subscales were standardized to a mean score of 50 (standard deviation=10); scores above a T-score of 70 were considered indicative of clinically relevant behavioral problems (Achenbach, 1991).

Statistical analysis

We studied the association between parental long-term tobacco smoking and offspring regular tobacco smoking ($\geq$ 1 cigarette/day in the preceding 12 months) among all youths who completed the 1999 GAZEL Youth study questionnaire. Parental data for this analysis came from the parent GAZEL study. After excluding youths with missing data on parental or own smoking behavior,

our study sample comprised 1121 individuals (in multivariate analyses the study sample was reduced to 1041). The analyses were conducted controlling for a) youth's sex and age and b) youth's sex and age, as well as family income, youths' regular alcohol use and history of disruptive behavioral problems. Next, we stratified the analyses on the reference parent's sex and tested whether the association between parental and offspring tobacco smoking varied according to whether the smoking parent was the youth's mother or father. All analyses were carried out using logistic regression with the SAS software (SAS Institute, 2006).

Results

Overall, 26.9% of study youths regularly smoked tobacco. We observed a graded association between parental smoking trajectory and offspring smoking, such that the prevalence of regular tobacco smoking was 25.1% among offspring of non-smokers, 27.4% among offspring of parents who reduced their levels of smoking during the study period, and 37.0% among offspring of persistent smokers (p -value=0.0009).

As shown in **Table 1**, these results were confirmed in regression analyses: adjusting for youths' age and sex, offspring of persistent smokers were two times more likely to smoke regularly than offspring of non-smokers. This association remained essentially unchanged after additionally adjusting for family income as well as youths' regular alcohol use and disruptive behavioral problems. In supplementary analyses, we found that youths whose parents were persistent smokers had elevated probability of heavy smoking defined as ≥ 10 cigarettes per day (fully-adjusted OR: 1.95, 95% CI 1.24-3.05) and early smoking initiation,

that is before age 12 (fully-adjusted OR: 2.55, 95% CI 1.54-4.22). Moreover, among offspring of persistent smokers, despite small numbers of cases, we observed a higher probability of smoking among offspring of heavy rather than moderate smokers (not shown).

Stratifying the analyses on parental sex (**Table 2**), we found that in spite of greater statistical power for paternal smoking, youths' smoking was more strongly related to maternal smoking (fully-adjusted ORs of regular smoking: 3.12, 95% CI 1.58-6.16 for persistent maternal smoking vs. 1.47, 95% CI 0.87-2.49 for persistent paternal smoking). The effect of maternal smoking was consistently stronger than that of paternal smoking with regard to offspring heavy smoking and early smoking initiation, and did not vary with offspring sex (results not shown).

Discussion

In a large community-based sample of adolescents and young adults, we found that children of persistent smokers were disproportionately likely to smoke tobacco. In particular, rates of regular smoking were elevated among youths whose mother was a long-term smoker. To our knowledge, this is one of few studies testing the association between parents' long-term smoking trajectories and youths' smoking. Our results contribute to evidence suggesting that parents' smoking patterns have lasting influence on their children.

Methodological issues

Several methodological issues need to be discussed prior to interpreting these findings. First, only half of the original GAZEL Youth study sample

participated in the follow-up and participants were characterized by lower parental smoking rates than non-participants. Reassuringly, rates of tobacco smoking among participating youths are comparable to those observed in nationally representative studies in France (Choquet et al., 2000; Melchior et al., 2008). Nevertheless, parents' smoking rates were lower than in the general population (12.9% vs. 27.7%)(Guilber and Gautier, 2001); thus in other populations the association between parental and offspring smoking may be stronger than we report. Second, we assessed smoking in one parent, which may have resulted in incomplete ascertainment of parental smoking. However, past research reports high spousal concordance in smoking behavior, particularly when the woman is a smoker (Boomsma et al., 1994; Fagan et al., 2005; Vink et al., 2003). Additionally, regular smoking rates among youths appear similar whether one or both of their parents smoke (McGee et al., 2006; Paul et al., 2008). Thus, our use of data obtained from one parent is unlikely to have resulted in underestimation of the effect of parental smoking. A strength of our study is that parental smoking was ascertained prospectively over 11 years through direct parental reports, which are more precise than informant reports used in most previous studies (Bailey et al., 1993; Bauman et al., 1990; McGee et al., 2006; Paul et al., 2008). Additionally, respondents (both parents and youths) were blind to the research hypotheses tested in this study.

Mechanisms linking parental and offspring tobacco smoking

The intergenerational transmission of tobacco smoking is probably due to environmental and biological mechanisms. In our study, neither family

socioeconomic position nor youths' behavioral characteristics explained the association between parental and offspring tobacco smoking. Other potentially relevant environmental factors are the psychological influence of parental smoking on youths' behavior, parental transmission of positive norms regarding tobacco smoking, and parental tolerance of youths' smoking (Avenevoli and Merikangas, 2003; Darling and Cumsille, 2003; Fagan et al., 2005; Fidler et al., 2008). Additionally, approximately 50% of the parent-offspring transmission of smoking is thought to be genetic (Agrawal and Lynskey, 2008; Munafo and Johnstone, 2008). In particular, genes related to the metabolism of nicotine (ex. *CYP2A6*) or to the brain availability of neurotransmitters such as dopamine (ex. *DRD2*) or serotonin (ex. *5HTTLRP*) (Munafo and Johnstone, 2008) probably play a role. Additionally, prenatal exposure to tobacco may shape children's brain development in ways that increase predisposition to later tobacco dependence (Hellstrom-Lindahl and Nordberg, 2002) and is indicative of future risk of disruptive behaviors (Ernst et al., 2001), which in our study predicted youths' smoking patterns.

As other types of addictive behaviors, tobacco smoking probably results from interactions between genetic and environmental risk factors and the specific mechanisms of parent-offspring transmission have yet to be discovered (Munafo and Johnstone, 2008). Importantly, as illustrated by our findings, tobacco smoking frequently co-occurs with the use of other psychoactive substances such as alcohol, raising the question of whether smoking parents transmit to their children susceptibility to tobacco smoking as such or a general predisposition to

addictive behaviors. Due to small numbers, we could not test the association between parental alcohol abuse and youths' smoking behavior in our data, but this question should be examined in future research.

Study implications

Our findings indicate that parental smoking behavior is related to offspring tobacco use in adolescence and young adulthood. Thus, in examining factors associated with youths' smoking risk, it seems relevant to consider parents' long-term smoking trajectories, which can be assessed retrospectively. Moreover, encouraging parents to quit smoking may have beneficial effects not only for themselves but also for their children (Bricker et al., 2005; Exter Blokland et al., 2004; Kleinjan et al., 2009; McGee et al., 2006). Across industrialized countries, smokers are increasingly concentrated in tight clusters (Christakis and Fowler, 2008) and targeting families may be a propitious avenue for smoking prevention and cessation efforts.

Conclusions

Children of persistent smokers have high rates of regular tobacco smoking in adolescence and young adulthood. Helping parents reduce their levels of tobacco use may help decrease the burden of smoking in the next generation.

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Table 1. Parental tobacco smoking trajectory (1989-1999) and offspring regular tobacco smoking¹ in the Gazel Youth study (OR, 95% CI).

	OR (95% CI)
Age and sex-adjusted model	N=1121
Parental smoking trajectory: Non-smoker	1
Declining smoking	1.27 (0.77-2.10)
Persistent smoking	1.91 (1.30-2.79)
Youth's sex: Male	1
Female	1.22 (0.93-1.62)
Youth's age: 12-15 years	1
16-18 years	4.11 (2.45-6.91)
19-21 years	7.93 (4.75-13.24)
22-25 years	6.46 (3.88-10.75)
Fully adjusted model	N=1041
Parental smoking trajectory: Non-smoker	1
Declining smoking	1.14 (0.67-1.96)
Persistent smoking	1.96 (1.31-2.93)
Family income: >=800 euros/month per person	1
<800 euros/month per person	1.17 (0.86-1.60)
Youth's sex: Male	1
Female	1.46 (1.08-1.98)
Youth's age: 12-15 years	1
16-18 years	4.04 (2.33-6.99)
19-21 years	6.69 (3.87-11.58)
22-25 years	5.51 (3.15-9.61)
Youth's regular alcohol use: Absent	1
Present	3.27 (2.17-4.91)
Youth's disruptive behavioral problems: Absent	1
Present	2.36 (1.14-4.91)

¹ Regular tobacco smoking is defined as >=1 cigarette per day in the preceding 12 months.

Table 2. Maternal and paternal tobacco smoking trajectory (1989-1999) and offspring regular tobacco smoking¹ in the Gazel Youth study (OR, 95% CI).

	Maternal smoking trajectory	Paternal smoking trajectory
Models adjusted for youth' sex and age		
Parental smoking trajectory:	N=373	N=748
Non-smoker	1	1
Declining smoking	1.66 (0.62-4.40)	1.25 (0.69-2.28)
Persistent smoking	3.06 (1.61-5.82)	1.37 (0.84-2.26)
Fully-adjusted models²		
Parental smoking trajectory:	N=341	N=700
Non-smoker	1	1
Declining smoking	1.38 (0.48-3.98)	1.19 (0.62-2.26)
Persistent smoking	3.12 (1.58-6.16)	1.47 (0.87-2.49)

¹ Regular tobacco smoking is defined as ≥ 1 cigarette per day in the preceding 12 months.

² Adjusted for family income, youth's sex, age, regular alcohol use, and disruptive behavioral problems.