



Early Predictors of Trajectories of Tobacco Use Level from Adolescence to Young Adulthood: A 16-Year Follow-Up of the TEMPO Cohort Study (1999–2015)

Virgile Clergue-Duval, Murielle Mary-Krause, Camille Bolze, Eric Fombonne, Maria Melchior

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Early predictors of trajectories of tobacco use level from adolescence to young adulthood:

A 16-year follow-up of the TEMPO cohort study (1999-2015).

Abstract

Purpose

Individual and family characteristics early on in life are associated with adolescent smoking but their role with regard to long-term tobacco smoking trajectories into young adulthood is not well-known, which is what we set out to study using data from a longitudinal community-based cohort.

Methods

We used data from 2,025 youths throughout France (12-26 years at baseline, 16 years of follow-up) participating in the longitudinal TEMPO cohort study. Firstly, we modeled smoking trajectories from adolescence onwards using Group-Based Trajectory Modeling using the declared consumption of cigarettes at different ages. Secondly, among trajectories of smokers, associations with individual and family characteristics in childhood and adolescence were studied using multinomial logistic regression.

Results

We observed five smoking trajectories: non-smokers (62.3%), three groups of persistent smokers with different levels of tobacco use (low, intermediate, high) and a group characterized by high-level smoking followed by cessation. Among participants who were lifetime smokers ($n=763$), the trajectory of tobacco use was associated with early substance use initiation, academic attainment, grade retention, and parental smoking. Early tobacco and cannabis use initiation predicted high-level tobacco use whether it persisted ($OR=2.29$, 95% $CI=1.23-4.28$) or not ($OR=2.99$, 95% $CI=1.59-5.63$). Grade retention and parental smoking predicted persistent smoking of intermediate (respectively $OR=1.53$, 95% $CI=1.03-1.92$; $OR=1.74$, 95% $CI=1.03-2.92$) or high level (respectively $OR=1.74$, 95% $CI=1.07-2.85$; $OR=1.70$, 95% $CI=0.91-3.18$). Poor academic attainment predicted all three smoking trajectories, especially persistent high-level smoking (no high school degree: $OR=5.29$, 95% $CI=1.65-16.97$, vocational degree: $OR=1.94$, 95% $CI=0.99-3.80$).

Conclusions

Tobacco smoking trajectories from adolescence to adulthood are associated with early substance use initiation, parental smoking and academic difficulties.

Introduction

Tobacco smoking is the leading cause of preventable mortality, causing five million deaths per year in the world and bearing a global economic cost estimated at 1,436 billion US\$ [1,2]. Most smokers initiate tobacco use in adolescence. Within a few months of initiation, physical dependence and difficulty withdrawing can be observed [3]. In France, as in many industrialized countries, rates of tobacco smoking have diminished in the past 20 years, yet experimentation among adolescents remains high: by age 17 approximately 59% have experimented and 25% are daily smokers [4]. Tobacco use is multifactorial and influenced by family, individual as well as school characteristics including parental smoking, male sex, and the experience of behavioral and school difficulties [5–12]. Moreover, among adolescents as among adults, the likelihood of regular tobacco use follows a social gradient, that is persons who belong to socioeconomically disadvantaged groups are more likely to smoke than those who have a more favourable background [13]. These social inequalities have increased over time [14,15].

An important aspect of tobacco addiction is heterogeneity in the levels and patterns of use over time. However, while research shows that individual and familial factors, as well as socioeconomic characteristics, predict adolescent smoking [5–12], it is not known whether the same factors predict long-term smoking trajectories. The aim of our study, based on data from a longitudinal cohort, is to test the role of socioeconomic position, as well as other individual and familial vulnerability factors in childhood and adolescence, with regard to patterns of tobacco use up to adulthood.

Methods

Study population

Our investigation is based on data collected in the TEMPO cohort study, which aims to evaluate individual, familial and social determinants of mental health difficulties and addictive behaviors in young people [16]. Study participants were recruited in two stages (1991 and 2011) via their parents, who participate in the GAZEL epidemiological cohort study since 1989 [17]. In 1991,

parents were asked to complete questionnaires about the development and mental health of one of their children (aged 4 to 16 years, $n=2,582$) [18]. In 1999, these children (aged 12 to 26 years) were followed-up and completed a questionnaire regarding their living conditions, mental health, and addictive behaviors ($n=1,121$) [10]. In 2011, recruitment was extended to all young adults whose parents take part in the GAZEL study (aged 18 to 37 years, one person per family) and all participants completed a phone interview ($n=1,214$) [19]. Participants were contacted again in 2015 and completed a self-reported questionnaire ($n=786$), yielding up to four measures of tobacco use (1999, 2009, 2011 and 2015). At the time of study inclusion, GAZEL cohort study participants worked for the French national energy company of electricity and gas (EDF-GDF) and were civil servants with secure employment. TEMPO cohort study participants belong to families with at least one parent working in this large public utilities company. The TEMPO and GAZEL cohorts are managed by INSERM (French public research organization dedicated to human health). The TEMPO study received approval of bodies supervising ethical data collection in France (CCTIRS, CNIL, 908163).

Sample

The modelling sample for our study includes 2,025 TEMPO participants with complete data on all characteristics studied in relation to tobacco use trajectories and at least one measure of tobacco use. Compared to TEMPO participants with incomplete data ($n=393$), TEMPO participants included in our study were more likely to be female ($p<0.0001$), to have initiated tobacco and cannabis precociously ($p=0.0009$), less likely to have had juvenile behavioral problems ($p<0.0001$), more likely to have a general or technological vs. vocational high school degree ($p=0.0002$), more likely to have parents who were current or former smokers ($p=0.0004$), less likely to have parents who separated or divorced ($p=0.0007$) and less likely to have parents who worked in a manual or clerical occupation ($p=0.0017$).

Because non-smokers and smokers differ on numerous characteristics, to examine predictors of long-term tobacco smoking trajectories in a sample as homogenous as possible, we excluded participants who were never-smokers (n=1,262), yielding an analytical sample of 763 men and women who reported daily smoking (≥ 1 cigarette/day) at some point in time between adolescence and adulthood.

Measures

Tobacco smoking trajectories.

Tobacco smoking (i.e. and the number of cigarettes per day) was ascertained in 1999, 2009, 2011 and 2015. To determine participants' longitudinal smoking trajectory, we used Group-Based Trajectory Modeling [20,21]. Smoking trajectories were estimated among participants with at least one measure of tobacco use. To select the number of trajectories with the best fit for our data, we used the Bayesian Information Criterion (BIC) associated with each model. Then we: a) tested all possible combinations of cubic polynomial orders for trajectory shapes, b) used posterior probabilities of group membership (average posterior probability of assignment to each trajectory group, odds of correct classification, difference between the estimated group probabilities and proportion of the sample assigned to each group) to create trajectory group membership and c) assessed the quality of the model's fit to the data. This group-based modelling method assigns each participant to a smoking trajectory group.

Individual and family characteristics.

Individual and family characteristics previously associated with tobacco use in adolescence and/or young adulthood which we considered include participants' age at tobacco and cannabis initiation, juvenile behavioral problems, schooling characteristics, as well as familial characteristics [5–13,22].

Tobacco and cannabis initiation

Tobacco and cannabis initiation were ascertained in every wave of the TEMPO study since 1999. We used the median age of substance use initiation in France (14 years for tobacco, 16 years for

cannabis [23]) to dichotomize our measures (early vs. late or no initiation). Ages of tobacco and cannabis initiation were correlated (Cramer's $V=0.43$), therefore we combined these two indicators into a four-class variable (Early tobacco/Early cannabis; Early cannabis only; Early tobacco only; Late or no tobacco/Late or no cannabis).

Juvenile behavioral problems

Participants' juvenile behavioral problems (yes vs. no) were ascertained using the externalizing symptom scale of the Child Behavior Checklist (CBCL) [24] reported by parents in 1991 or by participants themselves in 1999. Following the CBCL coding rules, we considered that scores at or above the 85th percentile were indicative of clinically significant behavioral problems. This measure was not available for TEMPO participants recruited into the study in 2011, however this subgroup completed the Mini International Neuropsychiatric Interview (MINI) schedule on behavioral problems prior to age 16 years (≥ 2 positive answers were considered to be indicative of behavioral problems while growing up).[25].

Schooling characteristics

Schooling characteristics were ascertained using two variables: high school completion and grade retention. Because the first measures of tobacco use in our study were obtained when participants were adolescent, we used these early indicators of schooling rather than maximum educational attainment, which is generally achieved in young adulthood and could therefore be concurrent to smoking patterns which we studied. Participants' schooling characteristics were primarily characterized by self-reported high school completion (no high school degree, vocational high school degree, vs. general or technological high school degree). Access to high school and the type of diploma obtained are important indicators of academic success and later employment in France. Additionally, we also took into account parent (1991) or self-reported (1999, 2009 or 2011) grade retention in primary, middle or high school (no vs. ≥ 1 grade retention), which is frequent in France (in the generation studied approximately 40% of students were retained at least one year by age 15 years [26]) and indicates the presence of academic difficulties.

Family characteristics.

Family characteristics were reported by participants' parents in the yearly GAZEL study questionnaire [17] and by participants themselves in the TEMPO study (2009 or 2011). Parental tobacco smoking was defined by the highest smoking level of either parent: persistent smoker, former smoker and non-smoker. This information was obtained directly from one of the parents (generally the father) in the GAZEL study (1989-2015) [10] and from TEMPO participants (2009 or 2011) for the other parent. Parental socio-economic position was ascertained by the highest parental occupational grade reported by parents at the time of inclusion in the GAZEL cohort study in 1989 (manager; technician or administrative associate; manual worker or clerk). Parental divorce or separation prior to the participant's sixteenth birthday was reported by parents in the GAZEL study (1989-2015) [27].

Statistical analysis

After identifying tobacco smoking trajectories among TEMPO study participants who had at least one measure of tobacco use and complete data on all covariates (n=2,025), we studied characteristics associated with tobacco smoking trajectories among the 763 participants who were regular smokers at any point in time using multinomial logistic regression models (low-level persistent smokers served as the reference group). Our multivariate model included all factors associated with at least one type of smoking trajectory with a p-value ≤ 0.05 in the bivariate model as well as age and sex. All analyses were carried out using SAS 9.4 [28].

Results

Smoking trajectories

We identified five trajectories of tobacco use: non-smokers (n=1,262), three trajectories of persistent smoking of low (n=218), intermediate (n=301) or high level (n=130) and a trajectory characterized by high consumption that ceased at some point in time (n=114). The average number

of daily cigarettes smoked at the age of 25 years was 2.7 (standard deviation, SD=2.3) in the low-level use group, 8.1 (SD=3.1) in the intermediate level use group, 18.4 (SD=10.1) in the high-level use group, 12.1 (SD=5.6) in the group characterized by smoking cessation. In sensitivity analyses implemented among participants with a) at least two (27.9%) b) at least three (13.4%) and c) four measures (11.2%) of tobacco use available, the number and shape of smoking trajectories were unchanged.

Sample characteristics

Table 1 describes the characteristics of our analytical sample.

Individual and family characteristics and tobacco use trajectory

Bivariate associations between individual and family characteristics and participants' smoking trajectory are presented in **Table 2**. Overall, participants' smoking trajectories were associated with individual characteristics (age of substance use initiation, juvenile behavioral problems, schooling characteristics and grade retention). The only familial characteristic associated with smoking trajectories was parental tobacco use.

In multivariate multinomial regression models (**Table 3**), early initiation of tobacco and cannabis use was associated with persistent high-level smoking and high-level smoking followed by cessation. Early tobacco (but not cannabis) use predicted high-level smoking followed by cessation. Grade retention and parental tobacco use predicted persistent smoking of intermediate and high. Having no high school degree was associated with all three smoking trajectories. Participants who were in vocational training had elevated levels of persistent high-level smoking falling just short of statistical significance. Results of sensitivity analyses conducted among participants with two or three measures of tobacco smoking were consistent with our main findings.

Discussion

Using data from a large community sample of adolescents followed up to adulthood, we observed five trajectories of tobacco use: none, low-level, intermediate-level or high-level tobacco use that persists over time and high-level tobacco use followed by cessation. Among smokers, early

initiation of tobacco and cannabis use predicted long-term high-level of tobacco use, while school difficulties and parental smoking predicted smoking persistence. Poor academic attainment predicted intermediate or high-level smoking, especially if it persisted over time, indicating that socioeconomic inequalities with regard to lifelong smoking appear early in life.

Individual characteristics and tobacco use trajectories

Our study shows that factors associated with long-term tobacco use – particularly if it is high-level - include the age of substance use initiation and academic difficulties. In particular, our data confirm the predictive role of early tobacco and cannabis initiation, which are associated with elevated odds of persistent high-level smoking as well as high-level smoking followed by cessation [13]. Early substance use initiation could be indicative of a propensity for addiction – reflecting both genetic and environmental influences [29,30], which may lead to long-term patterns of substance use. Indeed, different single-nucleotide polymorphisms (SNPs) were found to be associated with nicotine dependence as well as with the maintenance of tobacco consumption [31,32]. Although peers' influence has been identified as a determinant of adolescent smoking [33], and particularly smoking initiation [34], we could not study the impact of peers' smoking status as it had not been ascertained. Moreover, it is difficult to determine the risk fraction of smoking directly attributable to genetic and environmental components. Early substance use initiation could also negatively impact youths' educational level, labour market participation, and mental health, further fueling addiction risk [22,35]. The role of early substance use appeared strongest with regard to high-level smoking followed by cessation, which could in part be explained by the high initial levels of smoking in this group. Since TEMPO study participants were aged 30-40 years at the time of the 2015 wave of follow-up, we cannot exclude that some relapsed to smoking subsequently.

As other studies conducted in different settings, we found that participants who did not achieve a high school degree, completed vocational (rather than general) education or experienced grade retention were more likely to smoke persistently and at high levels [13,14,36–38]. Smoking is a

social behavior – particularly in adolescence – and this finding highlights higher acceptability of tobacco use in socioeconomically disadvantaged groups [39]. These socioeconomic inequalities tend to further deepen during the lifecourse [15] implying that smoking prevention efforts should be implemented in ways that are relevant to youths across the socioeconomic spectrum.

Family characteristics associated with trajectories of tobacco use

As in previous studies, we found an association between parental and offspring tobacco use – particularly persistent long-term smoking [8,9]. Importantly, children of former smokers did not have a higher likelihood of smoking than those of non-smoking parents. Parental persistent smoking may reflect a stronger dependence to nicotine or a genetic propensity for addiction [40], but the relationship with offspring tobacco use could also reflect environmental influences such as easy access to tobacco products, parental tolerance of offspring smoking, and offspring modeling of parental behavior. Our data highlight the intergenerational benefits of smoking cessation, which should be brought to the attention of parents.

In our study, neither parental divorce/separation nor parental occupational grade were associated with offspring tobacco use. Prior research shows that children whose parents are separated or have low socioeconomic position are more likely to smoke in adolescence [5,13] – our findings suggest that these familial characteristic may not influence smoking patterns over the long-term above and beyond individual characteristics and parental smoking patterns. It is possible that in our sample of youths, who all had parents employed in a large public utilities company, parental divorce and low socioeconomic position were not frequent enough to influence offspring smoking rates.

Limitations and strengths

Our study has several limitations. First, TEMPO cohort study participants belong to families with at least one parent working for a single large national energy company (EDF-GDF) and who accepted to be part of a longitudinal follow-up [41]. Thus, our study does not include participants who come

from very disadvantaged socioeconomic backgrounds and the prevalence of smoking is somewhat lower than among young adults in France in the general population [14]. This type of selection bias is common in longitudinal cohort studies. Nevertheless, the TEMPO study participants are characterized by a diversity of profiles, ensuring sufficient heterogeneity to make comparisons across different groups. In the population at large, associations between key individual or family characteristics (e.g. academic difficulties) and individuals' smoking trajectories may be stronger than we report. Second, the statistical power of our analyses was limited for the study of some factors (for example the role of vocational training). Additional studies examining long-term smoking trajectories in larger samples with sufficient numbers in all groups (particularly smokers who quit and who are underrepresented prior to age 40 [42–44]) are needed. Third, we did not study certain factors associated with long-term smoking such as adverse childhood experiences and peer smoking because this information was not available for all participants included in our analyses [45,46].

Our study's main strengths are: 1) a longitudinal analysis of the influence of early life factors on long-term tobacco smoking in adulthood; 2) data regarding participants' family characteristics collected directly from parents.

Conclusion

In conclusion, through longitudinal data from childhood to adulthood which makes it possible to determine tobacco use trajectories, this study analyzed childhood and adolescence, including parental factors, associated with the patterns of tobacco use up to adulthood, most of the published studies investigating the association only in the adolescence. Our study shows that individual and family characteristics in childhood and adolescence are associated with the persistence and level of smoking from adolescence to adulthood. While early tobacco and cannabis initiation primarily predict high smoking levels - which persist or not - academic difficulties are the major factor associated with lasting patterns of high-level smoking. These socioeconomic inequalities in tobacco

use emerge early in life and should be specifically targeted by interventions aiming to decrease tobacco use among young people. And so, increasing efforts are necessary to prevent smoking and other forms of substance use among youths who have academic difficulties. Nevertheless, additional research will need to examine whether in a context of decreasing tobacco use levels in many industrialized countries, the influences of early life characteristics on long-term patterns of substance use evolve.

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Conflict of interest

The authors report no conflict of interest.

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Table 1. Characteristics of smokers included in the study (TEMPO cohort study, 1999-2015, France, n=763)

Age (in 2015) (mean. $\pm$SD)	35.1 years ($\pm$ 3.5)
Gender	
Male	339 (44.4%)
Female	424 (55.6%)
Age of substance use initiation	
Early tobacco / Early cannabis	143 (18.7%)
Early cannabis only	72 (9.4%)
Early tobacco only	172 (22.5%)
Late tobacco / late cannabis	376 (49.3%)
Juvenile behavioral problems	
Yes	153 (20.0%)
No	610 (80.0%)
Academic attainment	
< high school degree	49 (6.4%)
Vocational degree	96 (12.6%)
General or technological degree	618 (81.0%)
Grade retention	
$\geq$ 1 time	470 (61.6%)
Never	293 (38.4%)
Parental tobacco smoking	
Persistent smoker	131 (17.2%)
Former smoker	188 (24.6%)
Non-smoker	444 (58.2%)
Parental separation/divorce	
Yes	84 (11.0%)
No	679 (89.0%)
Parental occupational grade	
Manager	282 (37.0%)
Technician/administrative associate	416 (54.5%)
Manual worker/clerk	65 (8.5%)

Table 2. Individual and familial factors associated with trajectories of tobacco use from adolescence to young adulthood: bivariate multinomial regression model (TEMPO cohort study, 1999-2015, France, n=763, Odds-ratio (OR), 95% Confidence Interval (95% CI))

	Low-level tobacco use n=218	Intermediate-level tobacco use n=301 OR (95% CI) *	High-level tobacco use n=130 OR (95% CI) *	Smoking followed by cessation n=114 OR (95% CI) *
Age (in 2015)				
35-41 years	Reference	0.90 (0.63-1.28)	1.31 (0.83-2.07)	0.54 (0.34-0.86)
22-34 years		1	1	1
Gender				
Men	Reference	1.23 (0.86-1.75)	1.17 (0.75-1.81)	1.30 (0.83-2.06)
Women		1	1	1
Age of substance use initiation				
Early tobacco / Early cannabis		1.04 (0.62-1.74)	2.38 (1.32-4.30)	3.66 (1.99-6.73)
Early cannabis only	Reference	0.81 (0.44-1.49)	1.10 (0.50-2.43)	1.69 (0.77-3.73)
Early tobacco only		1.03 (0.66-1.62)	1.84 (1.06-3.18)	2.21 (1.22-4.00)
Late tobacco / late cannabis		1	1	1
Juvenile behavioral problems				
Yes	Reference	1.28 (0.81-2.02)	1.57 (0.91-2.71)	1.78 (1.02-3.11)
No		1	1	1
Academic attainment				
< High school degree		4.50 (1.53-13.29)	6.78 (2.15-21.36)	5.16 (1.58-16.88)
Vocational degree	Reference	1.72 (0.98-3.03)	2.50 (1.32-4.74)	1.03 (0.47-2.29)
General or technological degree		1	1	1
Grade retention				
≥1 time	Reference	1.66 (1.16-2.37)	2.17 (1.36-3.45)	1.03 (0.65-1.62)
Never		1	1	1
Parental tobacco smoking				
Persistent smoker		1.81 (1.08-3.01)	1.71 (0.93-3.14)	1.51 (0.79-2.89)
Former smoker	Reference	1.25 (0.82-1.88)	0.89 (0.52-1.53)	1.02 (0.59-1.77)
Non-smoker		1	1	1
Parental separation/divorce				

Yes	Reference	1.43 (0.81-2.53)	1.20 (0.58-2.46)	1.17 (0.55-2.48)
No		1	1	1
Parental occupational grade				
Manager		0.72 (0.50-1.04)	0.92 (0.58-1.44)	0.62 (0.38-1.02)
Technician/administrative associate	Reference	1	1	1
Manual worker/clerk		1.31 (0.69-2.50)	0.80 (0.32-1.96)	0.90 (0.38-2.14)

Statistically significant results are presented in bold type.

* In a multinomial regression model; odds-ratio indicate the probability of a modality as compared to the reference modality. The groups “intermediate level tobacco use”, “high level tobacco use”, “smoking followed by cessation” are compared to the “low level tobacco use” group.

Table 3. Individual and familial factors associated with trajectories of tobacco use from adolescence to young adulthood: multivariate multinomial regression model (TEMPO cohort study, 1999-2015, France, n=763, Odds-ratio (OR), 95% Confidence Interval (95% CI)).

	Low-level tobacco use n=218	Intermediate-level tobacco use n=301 OR (95% CI) *	High-level tobacco use n=130 OR (95% CI) *	Smoking followed by cessation n=114 OR (95% CI) *
Age (in 2015)				
35-41 years	Reference	0.88 (0.60-1.28)	1.46 (0.90-2.39)	0.66 (0.41-1.08)
22-34 years		1	1	1
Gender				
Men	Reference	1.07 (0.74-1.55)	0.95 (0.60-1.51)	1.22 (0.76-1.97)
Women		1	1	1
Age of substance use initiation				
Early tobacco / Early cannabis		0.92 (0.54-1.56)	2.29 (1.23-4.28)	2.99 (1.59-5.63)
Early cannabis only	Reference	0.85 (0.46-1.58)	1.22 (0.55-2.73)	1.68 (0.76-3.74)
Early tobacco only		0.97 (0.61-1.53)	1.67 (0.95-2.93)	2.17 (1.19-3.96)
Late tobacco / late cannabis		1	1	1
Juvenile behavioral problems				
Yes	Reference	1.07 (0.66-1.72)	1.23 (0.69-2.18)	1.48 (0.83-2.64)
No		1	1	1
Academic attainment				
< High school degree		4.03 (1.35-12.00)	5.29 (1.65-16.97)	4.09 (1.22-13.70)
Vocational degree	Reference	1.45 (0.81-2.61)	1.94 (0.99-3.80)	0.88 (0.38-2.01)
General or technological degree		1	1	1
Grade retention				
≥1 time	Reference	1.53 (1.05-2.22)	1.74 (1.07-2.85)	0.94 (0.58-1.53)
Never		1	1	1
Parental tobacco smoking				
Persistent smoker		1.74 (1.03-2.92)	1.70 (0.91-3.18)	1.42 (0.73-2.76)
Former smoker	Reference	1.24 (0.81-1.89)	0.86 (0.50-1.51)	0.99 (0.57-1.74)
Non-smoker		1	1	1

Statistically significant results are presented in bold type.

* In a multinomial regression model; odds-ratio indicate the probability of a modality as compared to the reference modality. The groups “intermediate level tobacco use”, “high level tobacco use”, “smoking followed by cessation” are compared to the “low level tobacco use” group.