Cigarette smoking trajectories from adolescence to young adulthood: first report from the Middle East

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Abstract

Background: This study is the first effort in the Middle East to identify cigarette-smoking trajectories and their predictors, from adolescence to young adulthood.

Methods: Using data from the Tehran Lipid and Glucose Study, 1169 adolescents (12–18 years old) were followed into their young adulthood (28–32 years old), from 2002 to 2016. Cigarette smoking (combination of quantity and frequency) was the outcome variable used for group-based trajectory modelling. After detecting the trajectories, the effects of independent variables (individual employment, education, physical activity, and paternal smoking, employment and education) on the trajectories were investigated.

Results: Three trajectories were detected: non-smokers (79%), experimenters (12%) and escalators (9%). Compared to girls, boys were approximately three times (OR=2.94, 95%CI: 2.32-3.24, $P<0.001$) and 25 times (OR=25.00, 95%CI: 26.08-23.92, $P<0.001$) more likely to be in the experimenter and escalator groups, respectively. Receiving a university education decreased the odds of placing in the escalator trajectory by 18% (OR=0.82, 95%CI: -0.04-0.96, $P=0.002$). Employment after high school increased the odds of following both experimenter trajectory (OR= 2.00, 95%CI: 1.42-2.50, $P=0.01$) and escalator trajectory by approximately twofold (OR=2.33, 95%CI: 1.33-2.93, $P=0.03$). Paternal smoking was associated with 1.88 and 2.23 increased odds of experimenting and escalating smoking in adolescents, respectively.

Conclusion: Iranian adolescents follow three trajectories – non-smokers, experimenters and escalators – into young adulthood. Male sex, employment after high school, and living with a smoker father are associated with unfavourable smoking patterns. These findings provide valuable insight that can be translated into practical interventions tailored to the local context.

Keywords: Smoking trajectories, cigarette smoking, adolescence, young adulthood, longitudinal

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Declarations

Ethics approval and consent to participate
The study was approved by the Ethical Committee of Research Institute for Endocrine Sciences and the National Research Council of the Islamic Republic of Iran (EC 121). Informed consent was obtained from all individual participants included in the study. All procedures were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent for publication
Not applicable.

Availability of data and materials
The data sets used and/or analysed during the study are available from the corresponding author on reasonable request.

Conflict of interest
The authors declare that they have no competing interests.

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Authors' contributions
HM-A and PA designed the study. FA and PA contributed to the design of the TLGS. LC conducted the statistical analysis. HM-A, SR, EA and LC contributed to interpretation of data. HM-A and SR contributed to writing the original draft. PA, FA and EA reviewed and revised the draft manuscript. PA and FA supervised drafting. All authors read and approved the final manuscript.

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Background

The negative health consequences of cigarette smoking and its attributed morbidity and mortality are well known *(1)*. As the most common type of tobacco use, cigarette smoking continues to be a public health problem. Globally, 22.3% of the population uses tobacco, 36.7% of all men and 7.8% of the world's women *(2)*. In the Islamic Republic of Iran, the prevalence of smoking and daily cigarette

smoking among adults in 2016 was 14.1 and 9.7%, respectively. The prevalence of smokers in adolescents was 3.4% *(3,4)*.

Cigarette smoking is a complex and dynamic behaviour that follows a progressive pattern throughout the life course *(5)*. Most adult smokers start smoking in adolescence *(6)*, making it a critical period in developing smoking behaviour. The importance of this period has made it the target of most smoking-prevention interventions for many years. Although effective in preventing and delaying smoking initiation, these interventions often fail to stop smoking progression *(7)*.

In adulthood, when smoking behaviour has already been established, the focus shifts towards cessation interventions. Therefore, the path between experimentation with tobacco products and established smoking behaviour that occurs during young adulthood is often neglected *(8,9)*.

The dynamicity of smoking behaviour makes it logical to examine its longitudinal pattern to understand how and when this behaviour forms in different subpopulations. Trajectory analysis can help describe the longitudinal trend of cigarette use, identify subgroups at risk of sustained and heavy smoking, and pinpoint the optimum time to intervene *(10,11)*.

Many North American and European cohort studies have used this method to identify smoking trajectories *(11)*. While most of them traced smoking into adolescence, few have examined smoking behaviours from adolescence through young adulthood *(12–17)*. Previous studies also varied in duration of follow-up (between 1.5 and 23 years) and measurement intervals (between three months and 4.5 years) *(11)*. Researchers used different indicators for smoking in previous articles, including smoking frequency (number of days of smoking in a period of time), smoking intensity (number of cigarettes smoked in a defined time) and a combination of intensity and frequency.

Given the methodological and analytical disparities, the observed trajectories in prior research diverged in terms of quantity, ranging from two to six. Studies with fewer data points detected a lower number of trajectories. In terms of typology (the visual inspection of the curves), trajectories with lowest level of cigarette consumption were the most prevalent, followed by increasing pattern.

In the existing body of literature, various factors have been identified as predictors of cigarette smoking-trajectory membership. These include age, sex/gender, race, parental education and smoking, peers' smoking, other substance use, and depression. While some of these predictors remain consistent over time, such as race and sex, others, such as socioeconomic and behavioural predictors, are subject to change throughout the lifespan. However, these results are not generalizable to the countries with socio-cultural differences.

Results from longitudinal studies in Middle Eastern countries, including Iran, indicate high progression rates from the primary stages of the smoking behaviour spectrum to established consumption in school years *(18–20)*. Yet, with the maximum follow-up time of three years, few of them have delved into changes in smoking behaviour in the transition from adolescence to young adulthood.

The Tehran Lipid and Glucose Study (TLGS), one of the unique longitudinal cohorts in the Middle East, provides an opportunity to conduct advanced analysis on tobacco-related data and prepares preliminary data for designing age- and stage-sensitive interventions in the region. Leveraging the TLGS data, this study is designed to fill the gaps mentioned above and enrich the smoking-related literature on the topic.

The first objective of the study is to identify the developmental trajectories of cigarette smoking from adolescence to young adulthood. The second objective is to identify the individual and parental predictors of the membership of each trajectory.

Methods

Sampling and participants

Data is drawn from TLGS, an ongoing family-based cohort study to capture non-communicable disease prevalence and risk factors in an urban population of Iran. The multistage cluster random sampling method was used to select the target sample. In stage one, three of the 20 health care centres in district 13 of Tehran were selected, based on geographical location and data availability.

In the second stage, the data of 15 005 residents (≥3 years) were randomly collected from those health care centres. TLGS included a cross-sectional phase (1999–2001) with five follow-up examinations at three-year intervals (2002–2004; 2005–2007; 2008–2010; 2011–2013; and 2014 –2016). Details of TLGS design and sampling were previously published *(21)*.

This study was restricted to participants aged 12–18 years (n=1567), who were followed from 2002 to 2016. After excluding 396 individuals with at least three missing in the smoking variable and two individuals who died over the follow-ups, analysis was conducted on the data of the remaining 1169 participants. The median follow-up for the whole population was 12.5 years.

Measurements

Smoking: As per previous use in the literature *(11,22)*, in order to concisely capture diverse patterns of smoking behaviour (especially occasional smoking, whose pattern may not be succinctly captured solely with frequency and intensity variables), we created a metric for smoking by combining intensity and frequency. At each follow-up measurement, smoking data was acquired using standard questionnaires. Adolescents (≤18 years) reported their quantity (number of cigarettes in one day) and frequency of smoking (number of days in the past 30 days).

We categorized each variable as follows: quantity: <1, 1–5, 6–10, 11–19, ≥20; and frequency: 0, 1–2, 3–14, 15–29, 30. We then multiplied the categorical quantity and frequency variables to obtain a single outcome measure (smoking index) that ranged from zero to 20. Adults answered the question about their current smoking with yes-every day, yes-occasionally and no. If they answered yes to the first question, they then reported the quantity (number of cigarettes) smoked per day and frequency (number of days) of smoking in the past seven days, which was converted to 30 days. Then, each variable was categorized and multiplied to reach the smoking index like the participants under 18 years of age.

Individual covariates: Employment status was defined as follows: before age 18, when attending school is compulsory, all participants were considered unemployed; and after 18 years of age (adulthood), anyone who reported a change in employment status to having a job was categorized as employed; otherwise, they were considered unemployed. A highly educated person was defined as someone who has studied for more than 12 years or reports university education after finishing high school. Binary sex was also added as covariate.

The Persian translation of the Modifiable Activity Questionnaire was used to assess physical activity (PA) in adolescents *(23)*. PA type (leisure and occupational activities), frequency and duration over the past 12 months were reported. The number of minutes/weeks for each activity was multiplied to its metabolic equivalent. Subsequently, an individual's total PA was calculated by adding up domains of PA, and levels were defined as low (<600 min./week) and high (≥600 min./week). For the purposes of this study, those with high PA in three of the five follow-ups were considered highly active.

Parental covariates: For each parent, employment was defined based on having or not having a job. Regarding education, parents were categorized as illiterate/primary, secondary/diploma, and higher. For their smoking status, parents were classified as current smokers (smoking always or occasionally) and non-smokers.

Statistical analysis

We used group-based trajectory models (GBTM) to identify cigarette-smoking trajectories from age 12 to 32. The analytic sample was 12–18-year-olds of baseline who became 28–32-year-olds in the last

follow-up. We estimated zero-inflated Poisson (ZIP) trajectory models with a user-written programme called TRAJ *(24)*. The zero-inflated model is used when analysing count data that has excess zero counts (zero-inflated). The excess zeros are suggested to be generated by a separate process from the count values and can be modelled independently. Therefore, the ZIP model combines two distributional forms: a Poisson count model and a Logit model for predicting excess zeros *(25)*.

To assess the appropriateness and suitability of the model, we created and examined visual representations depicting the distribution of the smoking index at baseline and subsequent follow-up examinations. Through the visual representations, we identified a significant number of zero values in the data, which aligned with our expectations given the age range of the participants, especially at baseline. These zero values correspond to individuals who can be categorized as non-smokers, indicating the absence of reported smoking.

At the beginning of the study, 98% of individuals had a smoking index value of zero. As the follow-up examinations progressed, the percentage of individuals with a zero smoking index decreased gradually, measuring 95%, 90%, 86% and 81% in the first through the last follow-up examinations, respectively. Subsequently, we investigated the possible number of latent trajectories by a series of models considering several linear and polynomial (cubic, quadratic) specifications of the smoking index as a function of age.

For better model detection, age was centralized at 20 years. GBTM *(10)* was used to identify subgroups of participants who shared similar underlying trajectories of the outcome variables. In a GBTM framework, the latent growth factors, that is, intercepts and slopes, determine each group's trajectory. The intercept refers to the initial smoking index for 20-year-old participants in phase two, and the slopes correspond to the rate of linear or non-linear change in the smoking trajectory across assessments. Adding quadratic or cubic growth parameters to the model helped to capture nonlinear trajectories.

We began with a single model consisting of one group and then increased the number of groups until the number of trajectories that best fit the data was identified based on the Bayesian Information Criterion (BIC), the average posterior probability of group membership (APP) and the odds of correct classification (OCC).

We tested models (see Table 1) with one to four groups and different specifications of smoking index as a function of age for each group and for zero-inflation probability. The three-group model with linear function of age for the first group and cubic function of age for the second and third groups was selected (model 12). The optimal model was selected as the lowest BIC (BIC= -2509.77), highest APP greater than 0.70, OCC more than five, and the minimum of 5% of the total sample for the size of each class. The same model with three groups and a quadratic function of age for zero-inflation probability (model 26) had a slight decrease in BIC value; however, as this model was more complex and model 12 was better interpretable, the former was chosen.

[ADD Table 1: Model fit indices for the trajectory model analysis NEAR HERE]

In this analysis, the BIC value increased for models with more than three trajectory groups. The models with four or more groups did not fit well and, as a result, the three-group model was considered optimal. For each subject, the model provides the probability of belonging to each of the identified trajectories and then assigns the subject to the group where it has the highest chance. Based on the existing literature, the selected model's substantive and theoretical interpretability were also considered.

While classifying the GBTM model, there was a possibility to add predictors to increase the accuracy of fit indices and shapes of trajectories. We included the effect of some previously studied covariates associated with smoking behaviours as time-stable predictors (individual sex, employment, education, physical activity, and paternal smoking, employment and education) on the defined trajectory groups. These covariates were included as time-invariant.

Missing data was handled using the STATA programme *(24)* in this study. The TRAJ programme uses the maximum likelihood method to estimate parameters, including group sizes and shapes of trajectories. When the data is assumed missing at random, this method generates an asymptotically unbiased parameter. Subjects with missing data are included in the analysis but only available data for each subject are used *(10)*.

To determine whether "missingness" affected the results (whether missing data is random or not), we explored missing data patterns and their effects on investigated smoking trajectories. A variable was created to represent the number of missing data among five data points for each participant and compared among three smoking-trajectory groups. In this study, there were potentially five data points for each participant.

In running the trajectory analysis, only participants with three or more available measurements of smoking are included; therefore, included participants may have zero, one or two missing smoking measurements. Having no or one missing data point in smoking was compared with having two missing data points, in prediction of trajectory membership. In addition, four dummy variables were made, representing missing data in the middle of follow-up examinations, and investigating the associations between any of these dummy variables and smoking-trajectory groups.

We conducted the trajectory analysis, including identification of the optimal trajectories and determining associated variables with the explored trajectories in STATA software version 16 and the remained analysis in IBM SPSS Statistics version 26; two-sided *P* values of <0.05 were considered statistically significant.

Results

The tested models in the GBTM are shown in Table 1. The APP of each group in the selected model ranged from 0.93 to 0.95, the estimated group sizes were close to the actual ones, and the OCC exceeded five, suggesting a good fit and accurate group assignment. The three groups were named as non-smokers (n=918, 79%), experimenters (n=146, 12%) and escalators (n=105, 9%).

As presented quantitatively in Table 2 and visually in Figure 1, the non-smokers represented the largest group in the sample, which followed intercept and a very slight linear trajectory.

[ADD Table 2: Parameter estimates of the trajectory model with a zero-inflated Poisson distributional form NEAR HERE]

[ADD Figure 1 NEAR HERE]

Both the experimenter and escalator groups had positive slopes, with negative quadratic function and positive cubic function of age. However, the magnitude of estimated parameters for slope, quadratic and cubic functions was smaller in the escalator group, causing a more-steeply increasing graph overall than the experimenter group.

The experimenters showed a smoking index similar to the non-smokers until 16 years of age and gradually increased their cigarette use into a young adulthood steady phase, which started to rise again at the age of 30. The escalators diverged from non-smokers and experimenters at age 14 and increased their cigarette smoking frequency/quantity with a negative quadratic trajectory followed by a late positive cubic trajectory.

Socio-demographic and behavioural characteristics of adolescents and their parents are represented in Table 3. The mean baseline age of adolescents was 15.14±1.97, 15.23±1.81 and 15.21±2.05 years, in non-smokers, experimenters and escalators, respectively. While boys comprised 35% of non-smokers, they formed the majority of the experimenters (70%) and escalators (89%). Experimenters were more

physically active. No significant difference was observed in parental characteristics between trajectories, except for paternal smoking (P<0.05).

[ADD Table 3: Baseline characteristics of adolescents and their parents according to smoking-trajectory group NEAR HERE]

Table 4 presents the effects of individual covariates in predicting trajectory membership, including participants' sex, education, employment, PA and missingness as well as paternal smoking status and missingness. Boys were three times and 25 times more likely than girls, respectively, to be experimenters and escalator smokers rather than non-smokers.

[ADD Table 4: Associated factors of the identified smoking trajectories using zero-inflated Poisson model NEAR HERE]

Receiving university education decreased the odds of placing in the escalator trajectory by 18% (P=0.001). Getting employed showed undesirable effects, as it doubled the odds of experimenter and escalator group membership (respectively, OR=2.00 and OR=2.33, P<0.05). High levels of PA had no significant effect in this regard.

Our model shows that, compared to those with no or one missing data point, adolescents with two missing data points are more likely to be in the escalator group (OR=2.03, 95% CI: 1.41-2.65, P=0.02). Paternal smoking (at any point during the study) is associated with 1.88- and 2.23-times higher odds of following an experimenter and escalator trajectory, respectively.

Discussion

Using data from TLGS, a population-based cohort study in the Islamic Republic of Iran, we followed 1169 Iranian adolescents for 15 years and identified three developmental trajectories of cigarette smoking: non-smokers (79%), experimenters (12%) and escalators (9%). Male sex, employment after age 18 and having a smoker father increased the likelihood of experimentation with smoking and continuing at a higher intensity. Participants with a university education were less likely to be escalator smokers. Physical activity level had no predictive value in trajectory-group membership.

In this study, using GBTM, we detected three distinct trajectories of cigarette smoking from adolescence to young adulthood. The majority of our sample was non-smokers. The second prevalent group was experimenters, with approximately one-sixth of the prevalence of non-smokers.

Experimenters started smoking at about 16 years of age at a low rate, increased their consumption from 18, and maintained a low-steady state between 24 and 30 years of age. This group seemed to increase cigarette smoking from the early fourth decade of their life.

Escalators, with less than 10% prevalence, started smoking increasingly from early adolescence (before 14 years of age). This increasing trend became steeper in young adulthood, highlighting the importance of this period.

Longitudinal studies from the Middle East region indicate high progression rates from the primary stages of the smoking behaviour spectrum to established school-age consumption. A large-scale study in Jordan showed a 38% increase in the frequency and intensity of smoking during three school years *(18)*.

In Iran, the transition rate from never smoking to experimentation has been reported to be between 10% and 14% in different adolescent samples. Moreover, 16-17% of novice smokers reported continued regular smoking after one to three years *(19,20)*. However, investigating the developmental pathways of smoking behaviour using different trajectory analysis methods has only been conducted in North American and European populations. Variations in the density of measurements, smoking indicators and time axis resulted in various numbers of trajectories between two and six *(11)*.

In line with our results, the most common finding in these studies was a large non-smoker group, which made up the majority of the sample. Occasional or light smoker, early-onset, and late-onset stable or increasing groups were other identified trajectories. Previous studies with relatively larger sample sizes, more data points or shorter time intervals detected additional smoking patterns, such as quitters or decliners *(15,17,26–28)*. These minority groups include adolescents who, despite smoking initiation, did not become established smokers.

In contrast, we did not detect such decreasing trends in our sample. The absence of a quitter group may be influenced by the characteristics of our study sample. It is possible that the prevalence of individuals who successfully quit smoking during the observed time period was relatively low or that the quitting patterns did not meet the criteria for forming a separate trajectory group. In this case, targeted interventions are needed in Iran to prevent smoking acceleration as mid- and late-adolescents move towards young adulthood.

On the other hand, the identification of specific trajectory groups depends on the underlying distribution of smoking behaviours and the fit of the statistical model to the observed data. Therefore, it is also plausible that the patterns of smoking cessation in our study did not exhibit clear trajectory profiles that could be distinguished from other trajectory groups. In this regard, future studies are needed to examine quitting trajectories and provide a comprehensive understanding of smoking cessation patterns.

Generally, participants' sex, education, employment and paternal smoking were predictive of trajectory-group membership in this study. In line with previous studies, we found that boys are more

likely than girls to follow the experimenter and escalator trajectory. However, the significant difference between girls and boys is consistent with previous studies in Iran, which might be related to the taboo of female smoking, and underreporting.

In this study, continuing education beyond high school is associated with reduced odds of smoking escalation. Education has been previously examined in relation to smoking trajectories with different indicators and definitions, such as academic performance through school years and years/level of education *(14,16)*. In line with our results, many studies found that education is a predicting factor in trajectory-group membership. In contrast, others have investigated education as an outcome of long-term smoking, showing that those who start smoking sooner and with increasing intensity have lower education and academic performance *(17)*.

Our data also showed that being employed after 18 is associated with membership of both riskier trajectory groups (experimenter and escalator). This finding contradicts previous studies that found unemployment increases the chance of being in high-risk groups. It might be interpreted that, in Iranian youth, employment does not act as a direct socioeconomic indicator but as a factor that could interfere with continued education after high school or cause low academic performance. As stated in previous studies, young Iranians in wealthier neighbourhoods smoke more than those in poorer areas *(29,30)*.

Our results show that paternal smoking was associated with 1.88 times higher odds of being in the experimenter group and doubled the odds of following an escalating trajectory. This is consistent with many studies confirming the association between parental smoking and adolescent smoking initiation and intensity *(11,31–33)*.

The intergenerational transmission could be due to more and easier access to cigarettes and weaker smoking policies at home. Although in previous studies, mothers' smoking had a stronger effect on offspring tobacco use *(32,33)*, studies of the TLGS sample did not find maternal smoking to be important in their children's smoking behaviours. This could be due to Iranian women underreporting their smoking and acting more conservatively in the family in this regard.

To the best of our knowledge, this study is the first effort to identify smoking developmental pathways in the Middle East region. With a large sample size and long follow-up time, the TLGS cohort study allowed us to examine trajectories of smoking behaviours from adolescence to young adulthood in association with some influential factors.

In this study, we created a metric for smoking by combining intensity and frequency to better capture diverse patterns of smoking behaviour (especially among occasional and non-daily smokers). This method has been used in previous studies investigating trajectories of cigarette smoking *(11,22)*. While our study's predictors may align with previous findings, its significance lies in its focus on the Middle East region, and its potential to inform targeted interventions and policies that are culturally appropriate and address the challenges and dynamics of the Middle Eastern context.

Our findings have the potential to guide targeted and tailored interventions that address the needs and challenges faced by individuals within each identified trajectory. Given that the majority of the sample consisted of non-smokers, it is crucial to maintain and reinforce this non-smoking behaviour. Thus, prevention programmes should focus on promoting and strengthening the non-smoking trajectory.

Recognizing their trajectory, early intervention can be designed to target experimenters during late adolescence and young adulthood. These interventions should emphasize the risks associated with continued smoking and provide support for smoking cessation and behaviour change. Future studies are needed to investigate the triggers or reasons behind the increase in smoking during the early fourth decade of life to prevent escalation.

Targeted intervention for escalators who are at high risk for long-term smoking and associated health consequences should be developed and implemented to address this group's needs, focusing on preventing the acceleration of smoking behaviour in young adulthood.

Limitations

In the analysis of this study, we were unable to capture the effects of variables that could vary over time due to data availability. Although these covariates were included as time-invariant, we defined their categories to detect one-point changes throughout the study. For example, a change in employment status was defined as a change from unemployment to having a job in any follow-up after age 18. More prospective research is needed to examine the effect of time-varying data on smoking trajectories.

Due to low prevalence of smoking in girls, we could not examine parental smoking influences on boys and girls separately in this study. Future studies with adequate sample size are needed to assess the sex-specific smoking trajectories in Iran. This study is also limited by self-reported questionnaires, which may have been prone to underreporting and recall bias, especially in women.

As the data were unavailable, other tobacco-related factors, such as mental health, family structure, peer smoking, attitudes and beliefs towards smoking, other risky behaviours and use of other substances like alcohol were not considered in this analysis.

Another limitation of our study is the potential presence of sampling bias. Our sample was drawn from urban areas of the capital city of Tehran, which may not be fully representative of the broader population in Iran or the Middle East. It is important to consider this potential bias when interpreting the results and applying them to wider populations. To mitigate this bias, future studies should aim for more diverse and representative samples that encompass different regions, socioeconomic backgrounds and cultural contexts within the Middle East. This would enhance the external validity and generalizability of the findings and provide a more comprehensive understanding of cigarette-smoking trajectories in the region.

Additionally, our study focused on adolescents and young adults, and the findings may not fully capture the smoking trajectories and predictors beyond this age range. Future research should consider extending the study duration and including participants across a broader age range to examine the long-term trajectories and predictors of smoking behaviour.

Conclusion

Iranian adolescents follow three trajectories – non-smokers, experimenters and escalators – to young adulthood. Male sex, employment after high school, and living with a smoker father are associated with unfavourable smoking behaviour patterns. On the other hand, continued education has protective effects against increasingly high levels of cigarette use.

Table 1: Model fit indices for the trajectory model analysis

Model No.	No. of groups	Order	BIC[1] (N=1169)	BIC[2] (N=4996)
I-order: 1				
1	1	1	-3122.69	-3125.59
2		2	-3101.01	-3104.64
3		3	-3086.28	-3090.64
4	2	1,1	-2798.13	-2803.22
5		1,2	-2782.85	-2788.66
6		1,3	-2777.37	-2783.91
7	3	1,1,1	-2540.74	-2548.00
8		1,1,2	-2523.87	-2531.86
9		1,2,2	-2518.45	-2527.16
10		1,3,2	-5308.50	-5317.94
11		1,2,3	-2515.35	-2524.79
12		**1,3,3**	**-2509.77**	**-2519.93**
13	4	1,1,1,1	Na	Na
14		1,2,2,2	-2892.19	-2903.08
I-order: 2				
15	1	1	-3106.75	-3110.38
16		2	-3086.42	-3090.78
17		3	-3076.76	-3081.84
18	2	1,1	-2788.71	-2794.52
19		1,2	-2774.06	-2780.59
20		1,3	-2771.07	-2778.33
21	3	1,1,1	-2528.22	-2536.21
22		1,1,2	-2511.99	-2520.70
23		1,2,2	-2511.43	-2520.87
24		1,2,3	-2509.14	-2519.31
25		1,3,2	-2510.37	-2520.53
26		**1,3,3**	**-2507.35**	**-2518.24**
27	4	1,1,1,1	-2538.20	-2520.53
28		1,2,2,2	Na	Na

Order: Polynomial (0=intercept, 1=linear, 2=quadratic, 3=cubic) for each group; I-order: Polynomial (0=intercept, 1=linear, 2=quadratic) zero inflation probability logit for each group.

BIC relates to the overall sample size and BIC relates to the subject sample size. NA: Not appropriate.

Reports are the number of participants in each trajectory group (n), the posterior probability of group membership estimated by model (Estimated), the actual likelihood of subjects assigned to each trajectory using the maximum probability rule (Assigned), the Bayesian Information Criterion (BIC), the average of posterior probabilities in each trajectory (APP), and the odds of correct classification in each group.

Figure 1: Trajectories of cigarette smoking from adolescence to young adulthood

Table 2: Parameter estimates of the trajectory model with a zero-inflated Poisson distributional form

	Estimate	SE	*P* value
Model component			
Count (Poisson)			
Smoking-trajectory group†			
Non-smoker trajectory			
Intercept (centred at 20 years)	-6.92	1.32	<0.001
Linear age	-5.09	2.15	0.02
Experimenter trajectory			
Intercept (centred at 20 years)	1.28	0.12	<0.001
Linear age	2.03	0.53	<0.001
Quadratic age	-4.22	1.06	<0.001
Cubic age	2.17	0.67	0.001
Escalator trajectory			
Intercept (centred at 20 years)	2.24	0.04	<0.001
Linear age	1.45	0.13	<0.001
Quadratic age	-2.19	0.36	<0.001
Cubic age	1.11	0.27	<0.001
Zero-Inflation (binomial)			
Intercept (centred at 20 years)	0.65	0.11	<0.001
Linear age	-2.33	0.22	<0.001

† Optimal selected three-group model with linear function of age for the first group and cubic function of age for the second and third groups. The intercept refers to the initial smoking index for 20-year-old participants in phase two, and the slopes correspond to the rate of linear or non-linear change in the smoking trajectory across assessments.

Table 3: Baseline characteristics of adolescents and their parents according to smoking-trajectory group

	Non-smokers n=918	Experimenters n=146	Escalators n=105	*P* value*
Adolescents' characteristics				
Age	15.14±1.97	15.23±1.81	15.21±2.05	0.09
Male sex	325 (35.4%)	102 (69.9%)[a]	94 (89.5%)[b]	<0.001
High physical activity	340 (53.9%)	77 (70.6%)[a]	55 (63.2%)	0.002
Smokers	2 (0.2%)	4 (2.8%)	17 (16.2%)	<0.001
Smoking index	0.002 ± 0.05	0.03 ±0.22	0.66 ±1.93	0.001
Maternal characteristics				
Age	41.28±6.41	42.12±6.85	42.50±5.83	0.08
Education level				0.47
Primary	460 (51.5%)	82 (57.7%)	60 (57.1%)	
Secondary	378 (42.3%)	51 (35.9%)	41 (39.0%)	
Higher	55 (6.2%)	9 (6.3%)	4 (3.8%)	
Occupation				0.76
Unemployed	825 (92.5%)	129 (90.8%)	96 (91.4%)	
Employed	67 (7.5%)	13 (9.2%)	9 (8.6%)	
Smoking				0.35
Yes	47 (5.3%)	11 (7.7%)	8 (7.6%)	
No	845 (94.7%)	131 (92.3%)	97 (92.4%)	
Paternal characteristics				
Age	47.03±7.55	48.33±7.90	48.24±7.89	0.47
Education level				0.06
Primary	347 (43.1%)	47 (38.5%)	53 (57.0%)	
Secondary	313 (38.8%)	56 (45.9%)	24 (25.8%)	
Higher	146 (18.1%)	19 (15.6%)	16 (17.2%)	
Occupation				0.15
Unemployed	115 (14.3%)	21 (17.4%)	20 (21.5%)	
Employed	691 (85.7%)	100 (82.6%)	73 (78.5%)	
Smoking				0.003
Yes	367 (45.9%)	67 (55.4%)	58 (62.4%)[b]	
No	433 (54.1%)	54 (44.6%)	35 (37.6%)	

Data are presented as numbers (%), mean ± (SD).

**P* values were achieved using chi-square and one-way ANOVA for categorical and continuous variables, respectively.

[a] significant difference between experimenters vs non-smokers.

[b] significant difference between escalators vs non-smokers.

Table 4: Associated factors of the identified smoking trajectories using zero-inflated Poisson model

Smoking-trajectory group	**Non-smokers**	**Experimenters**			**Escalators**		
Predictors		**Odds ratio**[†]	**SE**	***P* value**	**Odds ratio**	**SE**	***P* value**
Sex							
Boys (vs girls)	reference	2.94	0.23	**<0.001**	25.00	0.56	**<0.001**
Education							
Higher educated (vs low)	reference	0.09	0.23	0.69	0.82	0.25	**0.001**
Employment							
Employed (vs unemployed)	reference	2.00	0.27	**0.01**	2.33	0.40	**0.03**
Physical activity							
High (vs low)	reference	0.99	0.24	0.96	0.87	0.27	0.60
Adolescents' smoking missingness*							
Two missing data points (vs no or one missing data points)	reference	0.95	0.31	0.89	2.03	0.31	**0.02**
Paternal current smoking							
Yes (vs no)	reference	1.88	0.23	**0.005**	2.23	0.27	**0.003**
Paternal smoking missingness							

Having missing (vs not having missing)	reference	1.93	0.30	**0.03**	1.29	0.41	0.55

†Odds of being in each smoking-trajectory group compared to the non-smoker's trajectory. Model adjusted for sex, employment, education, physical activity and missingness.

*This variable represents the number of missing data among five data points for each participant. In this study, there were potentially five data points for each participant. For running the trajectory analysis, only participants with three or more available measurements of smoking are included; therefore, included participants may have zero, one or two missing smoking measurements. Having no or one missing data point in smoking was compared with having two missing data points, in prediction of trajectory membership.

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