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A Group-Based Modeling Approach to Identify Developmental Trajectories of Nicotine Dependence Among Lebanese Adolescents Waterpipe Smokers

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Abstract

Introduction: Adolescence represents a critical period in which nicotine dependence (ND) symptoms are developing. Little is known about waterpipe (WP) smoking and developmental trajectories of ND criteria across adolescence.

Aims and Methods: Here, we aimed to identify ND trajectories from early- to late-adolescence in current (past 30 days) WP smokers and examine baseline correlates of each identified trajectory, using the International Classification of Diseases, 10th Revision (ICD-10). The analytical sample consisted of 278 current WP smokers from eight waves of an ongoing longitudinal cohort of eighth to ninth graders in Lebanon. Group-based trajectory modeling was estimated to identify trajectory classes for ICD-10-ND criteria over ages 11–18.

Results: A group-based modeling approach yielded a four-class solution that best fit the data and reflected differences in the timing of ND onset during adolescence: no-onset of ND (43.9%), early-onset (16.2%), mid-onset (26.6%), and late-onset (13.3%) of ND criteria. Having a less-educated mother (adjusted odds ratio [aOR] = 4.08, 95% confidence interval [95% CI] = 1.01% to 16.53%) and siblings who smoke WP (aOR = 3.95, 95% CI = 1.08% to 14.42%), exposure to favorite WP-specific advertisements (aOR = 3.33, 95% CI = 1.03% to 10.85%), and being a novelty seeker (aOR = 1.12, 95% CI = 1.02% to 1.23%) were associated with early-onset of ND. Daily (aOR = 3.48, 95% CI = 1.08% to 11.23%) or weekly (aOR = 2.20, 95% CI = 1.05% to 4.62%) WP smokers (vs. monthly) and having

higher stress level (aOR = 1.07, 95% CI = 1.00% to 1.14%) were associated with mid-onset trajectory. Believing that WP smoking is not harmful to health (aOR = 0.11, 95% CI = 0.02% to 0.82%) and spending less than 60 minutes on a WP smoking session (aOR = 5.62, 95% CI = 1.20% to 26.44%) were associated with late-onset ND trajectory class.

Conclusions: Monitoring the development of ND trajectories among WP smokers may identify an individual as belonging to one of these four groups with distinct individual and socioenvironmental factors and allow the individual and health care providers opportunities to inform initiate on-time WP-specific tailored prevention and cessation interventions.

Implications: The results from this study showed a four-class trajectory of ICD-10-ND criteria and suggested that every ND trajectory class during adolescence could have distinctive characteristics and therefore provides new insights into the process of ND in terms of when and what specific interventions are needed to curb the development of ND and long-term WP smoking among youth.

Introduction

Waterpipe (WP; hookah, shisha) tobacco smoking is a widespread addictive and harmful behavior among young people in the Eastern Mediterranean Region.[1,2] In many Eastern Mediterranean Region countries, WP tobacco smoking is already more common than cigarette smoking, especially among youth.[1,3] For example, in 2017, current (past 30 days) tobacco use (mostly WP) was reported by 31.5% of Lebanese youth (age 13–15) compared with 11.2% who smoked cigarettes.[4] Adolescence represents an important developmental period in which exposure to nicotine can cause nicotine dependence (ND) and harm the developing brain, negatively impacting learning ability and attention.[5–7]

Understanding the characteristics of ND development in young WP smokers is needed to develop effective strategies and intervention to deal with it. WP tobacco smoking has several unique features that impact ND development in a way distinctive from cigarettes. Unlike smoking cigarettes, which is typically a solitary activity that takes about 5 minutes, a WP tobacco smoking session takes about 45 minutes, occurs in a relaxed socialized atmosphere, is stationary (WP is not portable like cigarettes), and can produce a pleasant aroma and taste that can serve as reinforcing sensory cues.[8]

The pace of development of ND also seems to be generally more rapid in WP smokers compared to cigarettes.[1,9,10] This is perhaps because of WP tobacco smoking's unique features and use patterns.[9,11] However, within the general time to ND anatomy, certain subgroups show unique patterns—pace—of ND development referred to usually as trajectories.[12] In cigarette smokers, knowledge of such trajectories has led to different developmental courses over time, which varies by the timing of onset, level of escalation, duration, and remission of symptoms.[12,13] While related trajectories are expected in young WP smokers, such analysis has not been conducted to date, mostly because of the lack of longitudinal data that documents the development of ND in young WP and cigarette smokers. Utilizing our pioneer prospective cohort data from the Waterpipe Dependence in Lebanese Youth (WDLY) study, we aim to (1) identify the distinctive developmental trajectory (latent classes) of ND among young people during an 8-year time span (ranged from age 11 to 18 years) and (2) determine individual and environmental risk factors that are associated with participants' membership in each ND trajectory class. Understanding the varied trajectories of WP ND and their associated sociodemographic characteristics will have important implications for cessation efforts in terms of when and what specific interventions are needed.

Materials and Methods

Study Design

Data for the present study were drawn from eight waves of an ongoing interview-based longitudinal study (WDLY) among 647 adolescents who were enrolled in eighth and ninth grades at baseline in spring 2015. Study design and procedures have been described elsewhere.[10,14] In brief, students from 38 (out of 178) public (n = 16) and private (n = 22) schools located in four regions of Lebanon (Beirut, Mount Lebanon, Nabatiye, and South Lebanon) were recruited and interviewed at 6-month intervals for waves 1–6 (2015–2018) and annually for waves 7 and 8 (2019–2020).

Ethical Considerations

For participants aged at least 18 years, written informed consent was obtained without the need for parental or guardian consent as opposed to those younger than 18 who provided parental consent in addition to their assents. This study was approved by the Institutional Review Boards of Florida International University and the American University of Beirut.

Cohort for Analysis

The current study assessed data from 278 adolescents who reported WP smoking in the 30 days prior to any of the eight waves. For this study sample (n = 278), while there was no loss to follow up between waves 1 and 2, the retention rates were 96% (n = 267, waves 2 and 3), 92% (n = 256, waves 3 and 4), 88% (n = 245, waves 4 and 5), 76.2% (n = 212, waves 5 and 6), 75.1% (n = 209, waves 6 and 7), and 71.6% (n = 199, waves 7 and 8). Overall, n = 79 WP smokers were lost to follow-up by wave 8, 49 (62.0%) of whom have already met ND criteria (see below for outcome variable information). Private and confidential face-to-face interviews were administrated to collect the data on WP use patterns, symptoms of ND, individual and environmental characteristics known to be associated with tobacco initiation, use behaviors, or ND.[9,15,16] We also collected the dates for smoking milestones, such as initiation or appearance of ND symptoms.[14,17] During each interview, we employed techniques (eg, personal calendar) to facilitate the accurate recall of dates and events.[17]

Measures

Outcome Variable

ND was defined based on the International Classification of Diseases, 10th Revision (ICD-10), which includes 19 items with

Yes or No response choices for each item. The ICD-10 has six criteria and attainment of at least three of these criteria during a 12-month period is required for the diagnosis of ND syndrome (see Supplementary e-Table 1).[18] In this study, the number of ICD-10-ND criteria was treated as an outcome variable (possible score 0–6). The ICD-10 has shown high reliability in adolescent smokers in both the WDLY study[14] and others.[16,17]

Covariates

The bassline covariates associated with ND were selected based on our previous work from the same cohort[11,19] and published literature.[20,21] We only used the baseline variables for our analysis since most (65%) of the participants who endorsed at least 1 ICD-10-ND criteria did so either prior to wave 1 or between waves 1 and 2. The covariates variable levels used as reference categories in regression models are underlined below.

Sociodemographic *v*ariables include age (years), gender (male or female), school type (public or private), mother and father education (<12 vs. ≥12 years of education), body mass index (BMI = weight in kg/height in m^2), and regular physical activity which is defined as performing the physical activity at least once a week (yes or no).

Smoking-*related characteristics* include having at least one siblings or friends who smoke WP or cigarettes (yes or no), parents smoke WP or cigarettes (mother or father who smoke WP or cigarettes (yes or no), believing that WP smokers have more friends (agree vs. disagree), believing that WP or cigarette smoking is harmful to health (agree vs. disagree), having favorite WP ads (yes or no), age of initiating WP smoking (years), frequency of use (using WP on a daily or weekly or monthly basis in the pasts month) and quantity of use (number of WP heads or bowls smoked in the past month), time spent during a typical WP smoking session (<30 minutes or 30–60/more than 60 minutes), and percentage of monthly income/allowance spend for WP (≤10% vs. >10%). To measure the monthly income/allowance of participants, we used a question asking, "What percentage of [monthly] income/allowance would you spend for WP smoking?" which was drawn from the Lebanon Waterpipe Dependence Scale (LWDS-10J).[22] The responses were "1% or less," "2%–10%," "11%–50%," and "more than 50%" of monthly income/allowance. Since less than 3% reported either "1% or less" or "more than 50%" of their monthly income/allowance spend for WP, we collapsed the categories as at most 10% versus more than 10%.

Psychological *i*ndicators include perceived stress was measured using a list of stressful life events (eg, loneliness, parental divorce) typically encountered during adolescence (15 items on a four-point Likert scale "Not at all (0) to A whole lot (3)" with a possible score of 0–45).[23] Depressive symptoms (six items on a four-point Likert scale "Never (0) to Often (3)" with a total score of 0–18) were measured using Mellinger Depressive Symptoms Scale.[24] Impulsivity (seven items on a five-point Likert scale "Not at all true (0) to Very true (4)" with 0–28 total score) was measured using a shortened version of the Eysenck Impulsivity Scale.[17,25] Novelty seeking (nine items on a five-point Likert scale "Not at all true (0) to Very true (4)" with 0–36 total score) was measured using Cloninger's Tridimensional Personality Questionnaire (eg, "When nothing new is happening, I usually start looking for something that is exciting").[17,26] Self-esteem (10 items on a four-point Likert scale "Strongly Disagree (0) to Strongly Agree (3)" with a total score of 0–30) was measured using Rosenberg Self-Esteem Questionnaire.[27] Students rated all psychological indicators based on their experiences on these events in the past 6 months preceding the survey. For all measures in this study, a higher score indicates that the participant is showing a higher endorsement of the psychological indicator. In this cohort, Cronbach's alpha of the psychological measures ranged from 0.63 to 0.81, indicating acceptable internal consistency.[11]

Statistical Analysis

The analysis approach is illustrated in Supplementary e-Figure 1. Semiparametric group-based modeling (SGM), an analytical tool that is available through a customized PROC TRAJ SAS macro developed by Nagin and coworkers,[28,29] was used to identify distinctive developmental trajectories of self-reported ICD-10-ND criteria among WP smokers from age 11 to 18 years.[28,30] The SGM, a type of latent class growth analysis, describes the course of behavior over age or time. The PROC TRAJ software is freely available online (http://www.andrew.cmu.edu/user/bjones/index.html). Because of the unequal time intervals between the interviews, we used a one-time varying covariate to adjust the dependent variable at each time point—namely the participants' age at the time of attaining ICD-10 criteria. PROC TRAJ allowed us to utilize all available data (including missing observations at some time points because of loss to follow-up) to estimate model parameters.[30–32] Because ND criteria were treated as a count outcome and were not normally distributed—because of a large number of zero responses for an outcome that resulted in skewed distributions—we applied zero-inflated Poisson distribution in the SGM.[30–32]

To determine the appropriate number of trajectory classes and shape for each class, a series of linear, quadratic, and cubic growth models (adjusted for age of smoking initiation and age at entry to the study) were estimated by fitting one to six classes. These growth models were estimated starting with a single class model followed by consecutively increasing the number of specified classes.[30] To construct a particular pattern of change, SGM provides a representation of the change trajectories commonly modeled via polynomial models (eg, quadratic, cubic) and is particularly useful for showing complex-shaped trajectories in a parsimonious manner.[33–35] Since the cubic term was not significant for all classes in our analysis, we applied quadratic term for all subsequent models. The appropriate number of classes was not known a priori; therefore, in order to determine the optimal and interpretable number of trajectory classes, we considered Bayesian Information Criteria (BIC) and Akaike Information Criteria (AIC) as indicators of model goodness of fit.[31] The lower BIC and AIC values mirror model parsimony, favoring a high log-likelihood estimate along with a lower number of parameters.[31] Participants are assigned to the trajectory for which they have the largest posterior probability estimate. The obtained posterior probability was used to assign each individual membership to the trajectory (class) that best fits their profile of change. According to Nagin et al.,[30,35] the average posterior probability of membership more than 0.7 was considered as a criterion to be included in the classes since it also indicates acceptable internal reliability.[32] The lowest membership probabilities were considered as 5% meaning that each potential class must have at least 5% of the sample.[32,36] The SGM approach produces both actual (observed) and predicted values[33] for each trajectory class that was also reported in this study. Our sample size was sufficient for SGM since this analysis approach can be applied to datasets of at least 100 cases.[31]

To ascertain whether baseline covariates varied by trajectory classes of ND, we performed a chi-square test for categorical variables and one-way analysis of variance for continuous variables. Baseline covariates with $p < .2$ in the univariate analyses[37] and theoretically ND-related

covariates (eg, gender and school type) were entered into the multinomial and multivariable logistic regression models to estimate adjusted odds ratios (aORs) and corresponding 95% confidence intervals (95% CIs) in a relationship to ND trajectory classes. In the multinomial logistic regression model, we compared three classes (early-, mid-, and late-onset) to no-onset class. Then, we conducted three multivariable regression models comparing three classes to each other (ie, early-onset vs. mid-onset, mid-onset vs. late-onset, and early-onset vs. late-onset). Analyses accounted for the clustering of students within schools. To compare the age of WP smoking initiation and trajectory classes, we classified adolescents into three groups based on their age of WP smoking initiation (ie, 12 or below, 13–15, and 16 or above). All analyses were conducted in SAS STAT statistical software (Version 9.4; SAS Institute, Inc, Cary, NC), and a two-sided $p < .05$ was considered statistically significant.

Results

Descriptive Results

At baseline, adolescents in the analyzed sample ($n = 278$) were on average 14.1 years old (SD = 1.2), 62.2% were female, 53.2% were enrolled in private school, and more than half had a parent (mother or father) with less than high school education (Table 1). There were significant differences between the four trajectory classes including age at baseline, having at least one sibling who smokes WP, believing that WP smoking is harmful to health, age at initiating WP smoking, frequency and quantity of WP use, time spent during a WP smoking session, having favorite WP ads, and novelty seeking.

Trajectory Class Characteristics

Table 2 presents fit statistics for the latent class growth modeling with 1–4 classes since the five-class solution was not viable because of false convergence in the model, meaning that PROC TRAJ failed to estimate model parameters for at least five classes. Therefore, we chose the growth model to specify the presence of four classes based on smaller BIC and AIC statistics with the proportion of classes (>5%) and the average posterior probability (for classes 1–4) as 0.98, 0.87, 0.94, and 0.95, respectively. As shown in Figure 1, each time point represents the estimated number of ICD-10 criteria (mean with corresponding 95% CI). Based on the aforementioned probabilities, it is estimated that 43.9% ($n = 122$) of the study sample belongs to *class 1* (no onset of ND symptoms; hereafter "no-onset"), 16.2% ($n = 45$) to *class 2* (early-adolescence ND onset; "early-onset"), 26.6% ($n = 74$) to *class 3* (mid-adolescence ND onset; "mid-onset"), and 13.3% ($n = 37$) to *class 4* (late-adolescence ND onset; "late-onset").

Overall, 56.1% ($n = 156$) of adolescent WP smokers experienced at least one ICD-10 criterion and 27% ($n = 75$) attained full syndrome of ND (ie, reached ≥3 of 6 ICD-10-ND criteria) between ages 11 and 18 years. Of these 75 WP smokers, 32.0% ($n = 24$) were in early-onset, 46.7% ($n = 35$) in mid-onset, and 21.3% ($n = 16$) in late-onset trajectory.

Correlates of Trajectories Membership

As displayed in Table 3, compared with the no-onset trajectory class, adolescents in the *early-onset* class initiated WP smoking at an earlier age (aOR = 0.52, 95% CI = 0.40% to 0.67%; $p < .001$) and were more likely to have favorite WP-associated advertisements (aOR = 3.33, 95% CI = 1.03% to 10.85%; $p = .048$), adolescents in the *mid-onset* class were more likely to be daily (aOR = 2.20, 95% CI = 1.05% to 4.62%; $p = .04$) and weekly smokers (aOR = 3.48, 95% CI = 1.08% to 11.23%; $p = .04$) compared to monthly, and report higher stress level (aOR = 1.07, 95% CI = 1.01% to 1.14%; $p = .049$), and adolescents in the *late-onset* class were less likely to believe that WP smoking is harmful to health (aOR = 0.11, 95% CI = 0.02% to 0.82%; $p = .03$), more likely to initiate WP smoking at an older age (aOR = 1.36, 95% CI = 1.06% to 1.75%; 0.02) and spend an average of more than 60 minutes on a WP smoking session (aOR = 5.62, 95% CI = 1.20% to 26.44%; $p = .03$).

Compared with the *mid-onset* trajectory class, adolescents in the *early-onset* class were more likely to have a less-educated mother (aOR = 4.08, 95% CI = 1.01% to 16.53%; $p = .04$), have at least one sibling who smokes WP (aOR = 3.95, 95% CI = 1.08% to 14.42%; $p = .04$), report higher score in novelty seeking (aOR = 1.12, 95% CI = 1.02% to 1.23%; $p = .02$), less likely to believe that WP smokers have more friends, initiate smoking WP at a younger age, and report lower stress (aOR = 0.86, 95% CI = 0.76% to 0.97%; $p = .01$) and self-esteem (aOR = 0.74, 95% CI = 0.61% to 0.90%; $p < .01$) levels. Compared with the *late-onset* trajectory class, adolescents in the early-onset class were less likely to initiate smoking WP at an older age (aOR = 0.39, 95% CI = 0.24% to 0.63%; $p < .001$).

As shown in Supplementary e-Figure 2, we classified adolescents into three groups based on their age of WP smoking initiation. Among those adolescents who started WP smoking at age 12 or below, 33% belong to early-onset, while it was 10.1% for those who started to smoke WP at age 13–15 and 0% for those who started at age 16 or over. This finding indicates a clear link between the age of smoking initiation and belonging to ND trajectory classes as it was also evident in our regression analysis.

Discussion

This pioneer longitudinal study sought to identify empirically ND developmental trajectory classes among adolescent WP smokers and their predictors using group-based trajectory modeling. In this study, more than half of the participants experienced at least one ICD-10 criterion spanning from 11 to18 years old, from which 27% met the full criteria for ND. Four classes provided the best fitting model with a spectrum of developmental trajectories of ND ranging from showing no symptoms (*no-onset*; class 1) to meeting diagnostic criteria for ND during early-adolescence (ie, *early-onset*; class 2), mid-adolescence (ie, *mid-onset*; class 3), and late- adolescence (*late-onset*; class 4).

Our findings revealed several differences among the identified ND classes in terms of sociodemographic, smoking patterns, and psychological characteristics. For example, compared with those without symptoms (no-onset), adolescents in the early-onset ND trajectory class were more receptive or exposed to tobacco advertising, in the mid-onset ND trajectory, there was a strong association with the magnitude of smoking frequency (ie, daily or weekly vs. monthly) and they reported a higher stress and self-esteem level, and in the late-onset trajectory, adolescents were less likely to believe that WP smoking can harm health and more likely to report a long smoking session. Compared to mid- or late-onset trajectory classes, adolescents showing early-onset ND had a mother with less than high school education, siblings who smoke WP, were novelty seekers, and reported low self-esteem.

In this study, the age-specific manifestations of ND symptoms allowed us to specify the ages (11–18 years) at which ND symptoms

Table 1. Prevalence or Mean of Covariates, Overall and by Nicotine Dependence Trajectory Class, WDLY (n = 278)

Variables	Overall, n = 278 n (%) or mean ± SD	No ND onset n = 122 n (%) or mean ± SD	Early ND onset n = 45 n (%) or mean ± SD	Mid ND onset n = 74 n (%) or mean ± SD	Late ND onset n = 37 n (%) or mean ± SD	p*
Gender (female vs. male)	173 (62.2)	76 (62.3)	27 (60.0)	41 (55.4)	29 (78.4)	.129
School (private vs. public)	148 (53.2)	71 (58.2)	23 (51.1)	37 (50.0)	17 (45.9)	.496
Age at baseline (mean ± SD)	14.1 ± 1.2	13.9 ± 1.5	13.5 ± 0.9	14.0 ± 0.9	15.4 ± 1.4	<.001
Mother' education (<12 years of education vs. ≥12)	160 (57.6)	62 (50.8)	30 (66.7)	43 (58.1)	25 (67.6)	.150
Father education (<12 years of education vs. ≥12)	182 (65.5)	70 (57.4)	30 (66.7)	54 (73.0)	28 (75.7)	.068
BMI, weight divided by height^2 (mean ± SD)	21.3 ± 4.0	20.8 ± 4.1	21.8 ± 4.5	21.5 ± 3.9	21.9 ± 3.4	.354
Physical activity (at least once or week) (yes vs. no)	199 (71.6)	83 (68.0)	30 (66.7)	60 (81.1)	26 (70.3)	.203
Parents smoke WP (yes)	153 (55.0)	66 (54.1)	24 (53.3)	46 (62.2)	17 (45.9)	.415
Having ≥1 siblings who smoke WP	149 (53.6)	63 (51.6)	33 (73.3)	34 (45.9)	19 (51.4)	.029
Having ≥1 friends who smoke WP	236 (84.9)	97 (79.5)	40 (88.9)	63 (85.1)	36 (97.3)	.051
Parents smoke cigarettes (yes)	187 (67.3)	87 (71.3)	27 (60.0)	51 (68.9)	22 (59.5)	.376
Having ≥1 siblings who smoke cigarettes	73 (26.3)	31 (25.4)	10 (22.2)	22 (29.7)	10 (27.0)	.826
Having ≥1 friends who smoke cigarettes	176 (63.3)	79 (64.8)	28 (62.2)	45 (60.8)	24 (64.9)	.946
Believing that WP smoking is harmful to health (agree vs. disagree)	43 (95.6%)	73 (98.6%)	32 (86.5%)	268 (96.4%)	120 (98.4%)	.005
Believing that cigarette smoking is harmful to health (agree vs. disagree)	272 (97.8)	119 (97.5)	44 (97.8)	73 (98.6)	36 (97.3)	.954
Believing that WP smokers have more friends (agree vs. disagree)	92 (33.1)	31 (25.4)	15 (33.3)	31 (41.9)	15 (40.5)	.080
Age of initiating WP smoking	13.3 ± 1.9	13.7 ± 1.7	11.6 ± 1.8	13.2 ± 1.4	14.4 ± 2.1	<.001
Frequency of WP use						.011
Monthly	132 (47.5)	72 (59.0)	18 (40.0)	29 (39.2)	13 (35.1)	
Weekly	93 (33.5)	37 (30.3)	14 (31.1)	29 (39.2)	13 (35.1)	
Daily	53 (19.1)	13 (10.7%)	13 (28.9)	16 (21.6)	11 (29.7)	
Quantity (number of WP heads or bowls)	9.5 ± 19.0	6.4 ± 12.9	17.1 ± 35.5	7.9 ± 10.4	13.7 ± 18.3	.005
Time spend during a WP smoking session						.009
Less than 30 min	147 (52.9)	77 (63.1)	19 (42.2)	37 (50.0)	14 (37.8)	
30–60 min	102 (36.7)	38 (31.1)	20 (44.4)	30 (40.5)	14 (37.8)	
More than 60 min	29 (10.4)	7 (5.7)	6 (13.3)	7 (9.5)	9 (24.3)	
Do you have favorite WP ads? (yes)	35 (12.6)	7 (5.7)	11 (24.4)	11 (14.9)	6 (16.2)	.008
Monthly income or vallowance spend for WP						.289
≤10% of income or allowance	252 (96.9)	113 (97.4)	37 (92.5)	70 (97.2)	32 (100.0)	
>10% of income or allowance	8 (3.1)	3 (2.6)	3 (7.5)	2 (2.8)	0 (0.0)	
Stress	7.6 ± 6.2	6.6 ± 5.7	8.0 ± 7.1	8.6 ± 5.9	8.6 ± 6.8	.112
Depression	7.1 ± 4.2	6.5 ± 4.4	8.0 ± 4.3	7.5 ± 3.9	7.3 ± 4.2	.157
Impulsivity	9.8 ± 6.0	9.2 ± 5.7	10.7 ± 6.6	10.0 ± 6.0	10.5 ± 6.3	.403
Self-esteem	20.9 ± 4.1	20.6 ± 4.0	20.2 ± 4.0	21.9 ± 4.0	21.4 ± 4.6	.086
Novelty seeking	13.8 ± 7.0	12.7 ± 7.0	16.0 ± 6.4	13.6 ± 7.4	15.4 ± 6.1	.030
Distractibility	7.9 ± 4.7	7.3 ± 4.6	8.3 ± 4.3	8.5 ± 4.9	8.7 ± 5.0	.232
Full syndrome of ND (yes)[a]	75 (27.0)	0 (0.0)	24 (53.3)	35 (47.3)	16 (43.2)	<.001

Class 1, resistant to ND symptoms onset; class 2, onset in early-adolescence; class 3, onset in mid-adolescence; and class 4, onset in late-adolescence. BMI = body mass index, ND = nicotine dependence, WDLY = Waterpipe Dependence in Lebanese Youth, WP = waterpipe. *Chi-square test for categorical variables and one-way analysis of variance for continuous variables.

[a]Logistic regression analysis (accounted for gender, school type, and age at smoking initiation did not show any significant differences between classes 2, 3, and 4 in terms of attaining full ND syndrome.

occur. Consistent with our previous studies from the same cohort[14,19] and cigarette literature,[12,13,15] this latent class analysis showed that the younger the age of smoking initiation, the faster the ND symptoms appear. In our analysis, a higher percentage of adolescents who developed full ND syndrome (46.7%) belonged to the mid-onset class that showed a strong association with frequency of use (daily/weekly). One interpretation for this finding is that the availability of WP and opportunities for smoking probably are much higher for this age group (13–15 years) than other age groups during adolescence, which partially supports why World Health Organization uses this age range to reports smoking prevalence among adolescents across the countries including Lebanon.[4]

Adolescents in the early-onset class were more receptive to tobacco advertising than their counterparts in the no-onset class. Most of the adolescents in this class began smoking WP when they were less than 13 years old, and this explains the fact that why they are one of the main target populations for WP advertisements in Lebanon.[38] This is not surprising since the WP tobacco industry,[39] especially in the Eastern Mediterranean Region, operates in an almost entirely unregulated market and employs deceptive marketing techniques to entice children as young as 13 years old with no policies in place to restrict underage access to WP smoking in WP-serving premises.[38,40,41] This lack of regulation facilitates youths' access to smoking which is an established predictor of the early appearance of ND symptoms as evident in our study.[38–40,42]

Our team and others previously highlighted some of the WP marketing tactics that attract youth. These include, but not limited to, promoting WP smoking on social media (eg, Instagram),[43,44] WP home delivery,[45] and marketing campaigns targeting youth and women.[3] The policy framework that allows Lebanon and other countries to respond to the WP epidemic is available through the Framework Convention on Tobacco Control (FCTC) treaty.[46,47] This global treaty outlines evidence-based tobacco control policies (eg, taxation, advertisement, health warnings, and clean indoor air) and has 182 parties with 168 signatories, including Lebanon.[46,47] Although some countries (eg, India, Turkey, United Arab Emirates, and Lebanon) have WP-related policies,[46,48] these policies are neither implemented nor enforced for the most part or are not adapted to WP-specific context and configuration.[49] For example, taxation needs to include other than WP tobacco (eg, devices, WP served in cafés), health warning labels need to be applied to the WP device, tobacco, and charcoal, and youth access should include not only purchased WP components, but those served in cafés and restaurants. Such adaptation and implementation will be crucial to the success of efforts to reduce WP smoking among youth and consequently tobacco-related morbidity and mortality.

Table 2. Test Statistics for Trajectories Nicotine Dependence (ICD-10 Criteria) Classes (n = 278)

Model	BIC	AIC	Class size
1	1206.44	1278.86	278
2	1131.85	1119.15	186, 92
3	1070.70	1050.74	175, 58, 45
4	**1023.73**	**994.71**	**122, 74, 45, 37**

AIC = Akaike Information Criteria, BIC = Bayesian Information Criteria, ICD-10 = International Classification of Diseases, 10th Revision. The five-class solution was not viable because of the failed convergence, meaning that the PROC TRAJ failed to estimate model parameters for ≥5 classes. The lowest value of BIC and AIC, highlighted in bold, was selected as an optimal model.

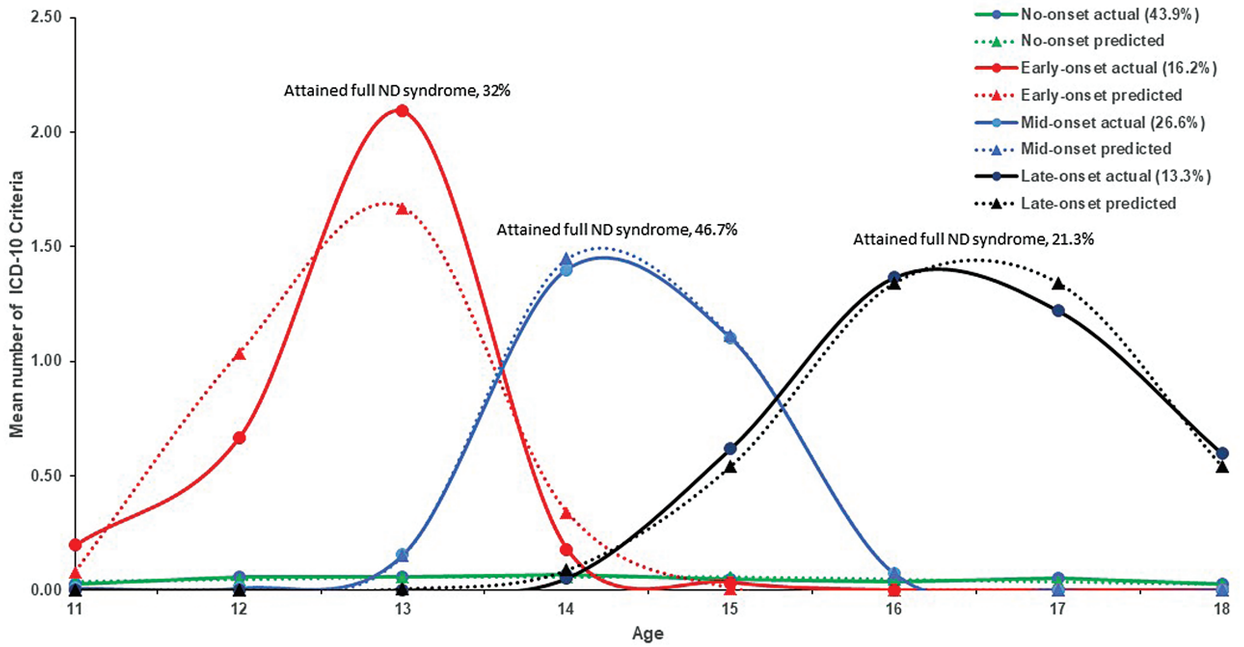

Figure 1. Trajectories of International Classification of Diseases, 10th Revision (ICD-10) nicotine dependence criteria in a four-class group-based trajectory model. *Note.* Class membership is based on average posterior probabilities without covariates in the model. Each time point (age) represents the mean of the number of ICD-10 criteria. The solid lines represent actual (observed) values of nicotine dependence (ND) trajectory classes, and the dashed lines represent predicted values of ND trajectory classes. The onset of ICD-10 nicotine dependence is reported as early-, mid-, and late-adolescence. Latent growth model was controlled for age at smoking initiation and age at the entry to the study to get a clear picture of ND trajectories during adolescence.

Table 3. Factors Associated With Developmental Trajectories of Nicotine Dependence in Four-Class Group-Based Modeling, WDLY (n = 278)

	Multinomial analysis (n = 278)			Multivariable analysis (n = 119)	Multivariable analysis (n = 82)	Multivariable analysis (n = 111)
	Early-onset vs. no-onset[a]	Mid-onset vs. no-onset[a]	Late-onset vs. no-onset[a]	Early-onset vs. mid-onset[b]	Early-onset vs. late-onset[b]	Mid-onset vs. late-onset[b]
Variables	aOR (95% CI); p	aOR (95% CI); p	aOR (95% CI); p	aOR (95% CI); p	aOR (95% CI); p	aOR (95% CI); p
Gender (female vs. male)	0.91 (0.35–2.33); .84	0.63 (0.30–1.29); .20	1.79 (0.62–5.19); .28	0.93 (0.26–3.30); .91	0.43 (0.08–2.42); .34	0.47 (0.13–1.67); .24
School (private vs. public)	0.95 (0.40–2.24); .90	0.62 (0.31–1.22); .16	0.71 (0.29–1.75); .46	2.40 (0.65–8.84); .19	2.12 (0.46–9.82); .34	0.90 (0.30–2.74); .85
Age at bassline (mean ± SD)	0.51 (0.29–0.91); .02	0.93 (0.64–1.34); .71	2.55 (1.57–4.14); .001	0.27 (0.11–0.67); .04	0.08 (0.01–0.45); .005	0.12 (0.04–0.35); .001
Mother' education (<12 years vs. ≥12 years)	1.45 (0.56–3.79); .45	0.84 (0.40–1.73); .63	2.14 (0.79–5.78); .13	4.08 (1.01–16.53); .04	1.48 (0.27–8.06); .65	1.76 (0.36–8.61); .48
Father education (<12 years vs. ≥12 years)	0.81 (0.31–2.12); .67	1.94 (0.89–4.22); .10	1.69 (0.60–4.76); .32	0.23 (0.05–1.02); .05	0.50 (0.08–3.04); .45	0.29 (0.07–1.22); .09
Having ≥1 siblings who smoke WP	1.55 (0.62–3.86); .35	0.63 (0.32–1.23); .18	0.69 (0.28–1.72); .43	3.95 (1.08–14.42); .04	2.26 (0.40–12.69); .36	0.69 (0.23–2.02); .49
Having ≥1 friends who smoke WP	1.17 (0.33–4.21); .81	1.19 (0.49–2.87); .70	6.86 (0.81–57.98); .08	0.23 (0.03–1.88); .17	0.07 (0.00–3.62); .18	0.07 (0.01–0.87); .04
WP smoking is harmful to health (agree vs. disagree)	0.76 (0.04–13.42); .85	1.83 (0.11–30.73); .68	0.11 (0.02–0.82); .03	0.30 (0.01–6.40); .44	15.53 (0.40–601.53); .14	10.48 (0.58–189.67); .11
Believing that WP smokers have more friends (agree vs. disagree)	0.77 (0.28–2.09); .60	1.72 (0.85–3.46); .13	1.45 (0.56–3.77); .44	0.20 (0.05–0.80); .02	0.51 (0.07–3.62); .50	1.09 (0.32–3.70); .90
Age of initiating WP smoking	0.52 (0.40–0.67); <.001	0.87 (0.71–1.05); .15	1.36 (1.06–1.75); .02	0.40 (0.25–0.64); .01	0.39 (0.24–0.63); <.001	0.56 (0.39–0.81); <.001
*Frequency of WP use (referent: monthly use)***						
Weekly	0.89 (0.32–2.49); .82	2.20 (1.05–4.62); .04	1.48 (0.54–4.07); .45	0.33 (0.09–1.25); .10	0.62 (0.10–3.76); .61	1.28 (0.35–4.71); .71
Daily	1.93 (0.49–7.62); .35	3.48 (1.08–11.23); .04	0.90 (0.19–4.32); .90	0.24 (0.03–2.33); .22	2.33 (0.14–39.52); .56	5.02 (0.56–44.69); .15
Quantity (number of WP heads or bowls)	1.01 (0.99–1.04); .35	0.99 (0.95–1.02); .39	1.00 (0.97–1.04); .78	1.06 (0.98–1.16); .16	1.00 (0.96–1.04); .91	0.96 (0.91–1.01); .14
*On average, time spend in 1 WP session (referent: <30 min)***						
30–60 min	1.25 (0.48–3.29); .65	1.35 (0.66–2.77); .41	1.47 (0.56–3.86); .44	1.11 (0.32–3.89); .87	0.96 (0.17–5.34); .97	1.22 (0.34–4.33); .76
More than 60 min	1.00 (0.20–5.06); 1.00	1.33 (0.35–5.11); .68	5.62 (1.20–26.44); .03	0.88 (0.11–7.19); .90	0.45 (0.03–7.36); .58	0.31 (0.05–2.05); .22
Do you have favorite WP ads? (yes)	3.33 (1.03–10.85); .05	2.01 (0.68–5.89); .20	2.47 (0.62–9.84); .20	1.95 (0.49–7.83); .35	2.21 (0.36–13.65); .39	0.66 (0.13–3.34); .62
Stress	0.97 (0.89–1.07); .55	1.07 (1.00–1.14); .05	1.05 (0.97–1.14); .20	0.86 (0.76–0.97); .01	0.93 (0.80–1.07); .28	1.01 (0.92–1.11); .89
Depression	1.05 (0.93–1.18); .47	1.04 (0.94–1.15); .43	0.94 (0.83–1.08); .38	1.01 (0.84–1.20); .94	1.25 (0.98–1.61); .07	1.12 (0.95–1.33); .18
Novelty seeking	1.04 (0.98–1.10); .22	0.98 (0.93–1.03); .35	1.04 (0.97–1.11); .31	1.12 (1.02–1.23); .02	0.99 (0.87–1.12); .82	0.95 (0.88–1.02); .12
Self-esteem	0.95 (0.85–1.06); .35	1.11 (1.02–1.20); .01	1.06 (0.96–1.18); .26	0.74 (0.61–0.90); <.01	0.86 (0.72–1.03); .10	1.05 (0.92–1.19); .51

aOR = adjusted odds ratio; 95% CI = 95% confidence interval, WDLY = Waterpipe Dependence in Lebanese Youth, WP = waterpipe. Multinomial and multivariable logistic regression models are adjusted for all covariates simultaneously. The sample size for each class that was used in regression analysis include no-onset class (n = 122), early-onset class (n = 45), mid-onset class (n = 74), and late-onset class (n = 37). **For variables with more than two categories, p-values (as a whole) were p = .2032 for smoking frequency and p = .3923 for time spend in 1 WP session.

[a]Multinomial logistic regression with the no-onset class as a reference category.

[b]Multivariable logistic regression models.

The observed nuances in the pace of development of ND symptoms during adolescence and associated predictors between trajectory classes that alluded to above can help to implement early (ie, prior to or in the first years of middle and high school) tailored intervention programs to reduce WP consumption, prevent the development of ND symptoms, and support cessation programs. These programs specifically include school-based educational interventions (eg, stress management techniques, increased self-esteem, educating parents, especially for those adolescents who have WP smokers in their family and are at greater risk of early WP smoking initiation and subsequently rapid experience of ND symptoms). Several tailored behavioral-counseling services could be helpful for adolescents who already developed full ND syndrome at an early age. For example, public health practitioners can assist adolescents with WP smoking cessation by following the "Five A's"—Ask, Advise, Assist, Arrange Follow-up, and Anticipatory Guidance.[50] These programs should address the specific features of WP smoking, such as its social dimension, unique experiences, and cues.

This study has some limitations. First, since ND trajectories were examined only for WP smokers, developmental patterns cannot be extended to cigarette smokers (because of the low sample size) in the WDLY study. Nevertheless, data from the next wave (wave 9) of the WDLY study will provide a unique opportunity to examine latent class analysis for cigarette smoking and how it differs from the trajectory classes among WP smokers in the same population extended to early adulthood. Second, the longitudinal nature of this study makes it prone to errors in recalling dates of ND milestones. However, we minimized such possibilities through employing techniques that improve event recall (eg, personal landmarks, bounded recall, decomposition, and a visual aid).[14,17] For this study, schools with eighth and ninth grades have participated from only four regions in Lebanon (Beirut, Mount Lebanon, Nabatiye, and South Lebanon) that were identified using a list from the Lebanese Ministry of Education. Although schools were considered eligible if they agreed to participate and provided space to ensure the privacy of interviews from the above-mentioned four regions, North and Bekaa areas with lower socioeconomic status and different demographics because of the influx of Syrian refugees issue were not included in this sample. Therefore, the findings may not be fully representative of all Lebanese public and private schools. Finally, some of the variables had wide confidence intervals (eg, beliefs about WP smoking, time spent in WP smoking sessions, and mothers' education), and for these variables, there is a small sample or cell size and multiple tests so it should be interpreted with caution focusing on the magnitude of effects and confidence levels rather than just *p*-values alone. Despite these limitations, our findings suggest that every ND trajectory class during adolescence could have distinctive characteristics and therefore provide new insights into the process of ND in terms of when and what specific interventions are needed to curb the development of ND and long-term WP smoking among youth.

Conclusions

Using a cohort of adolescents WP smokers, we showed that the developmental trajectories of ND vary during adolescence by the time of ND symptoms onset. We also revealed that the correlates of ND differ according to the developmental course. Identifying class membership among youth WP smokers should be critical for developing cessation interventions tailored to their specific characteristics.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at https://academic.oup.com/ntr.

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Declaration of Interests

Dr Eissenberg is a paid consultant in litigation against the tobacco industry and also the electronic cigarette industry and is named on one patent for a device that measures the puffing behavior of electronic cigarette users and on another patent for a smartphone app that determines electronic cigarette device and liquid characteristics. The other authors have no conflicts of interest to disclose.

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