A Study for Adolescent Substance Use Prevention : From the Longitudinal Perspective*

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In this paper adolescent substance use behavior is investigated from the longitudinal perspective with developmental trajectory methodology, which have been proposed to properly depict developmental change or growth. The longitudinal approach was used for the estimation of growth profiles represented by the parameters of initial status and the rate of growth. A longitudinal data set obtained from a prevention program for adolescent substance use was used in this study. Hypotheses concerning the form of growth in adolescent cigarette use, individual differences in the trajectory over time, and background variables influencing growth were tested. The analyses demonstrated that the quadratic growth curve was appropriate for modeling developmental process of adolescent smoking behavior. The schools that implemented the health education program showed a smaller rate of increase in smoking behavior.

Adolescent substance use behavior is no longer a matter of a few individuals in our society, but has become a national concern, which has to be understood in the context of social climate. In fact, an amazing number of adolescents are involved in smoking behavior. The age of beginning smoking behavior is an important contextual variable that influences the success of intervention programs. The risk factors can be divided into two categories. First group includes societal and cultural factors, which provide the legal and normative expectations for behavior. The second group

* This research was in part done while the author worked at International Bank of Research and Development. This Research was supported by grants given to the author from U. S. Department of Education, the U. S. National Science Foundation, the U.S. National Center for Educational Statistics, and the American Educational Research Association under Grant #RED-9452861. Opinions reflect those of the author and do not necessarily reflect those of affiliated institutions or granting agencies. Earlier versions of this paper were presented at the annual conference of American Educational Research Association, April16-19, 1999, Western Psychological Association, April 29-May 2, and American Society of Addiction Medicine, November 7-9, 1998.

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includes factors that lie within individuals and their interpersonal environments. Current knowledge about the risk factors for substance abuse does not provide a panacea for prevention, but it does point to potential routes for preventive intervention. Predecessors of smoking and alcohol problems have been described as risk factors for substance abuse. Risk factors occur before substance abuse and are associated statistically with an increased probability of drug abuse. A risk-focused approach seeks to prevent substance abuse by eliminating or mitigating its precursors.

This research suggests that a promising method for prevention research lies in testing interventions on early risk factors for substance abuse from the developmental point of view. Policies and health education programs need to become much more sensitive to understanding developmental profile of adolescent substance use behavior. Acknowledging growth profile requires an awareness of the initial status and growth rate of adolescent substance use behavior.

A substantial body of research on substance use has accumulated in the past several decades and has provided the empirical basis for identifying substance use and resiliency factors. Accumulated research findings have simultaneously provided the foundation for conceptual models for substance use. It is well known that, as an age group, youth are particularly susceptible to developing substance use problems. However, every adolescent is not at equally at risk; some are more clearly vulnerable than others. Therefore, it is critical to identify the risk and protective factors and the mechanism through which such factors work out. Much of the research on substance use has focused on youth in order to develop and test prevention approaches likely to be effective with this vulnerable age group. Many studies have contributed greatly to understanding the correlates and predictors of substance use among adolescent. Social-environmental factors associated with adolescent substance use include family or peer approval of drug use, family or peer models of substance use, peer pressure to use substance, and ready access to substance (see Murray& Hannen, 1990). Hawkins and his colleagues' social development model (Hawkins, Lishner, Catalano, & Howard, 1986) blends the work of earlier theorists. Hawkins et al. include elements of social control theory (Hirschi, 1969) and social learning theory (Bandura, 1977), and consider substance use experimentation from a developmental perspective in their model.

In this study we intend to apply the latent growth curve analysis to the investigation of adolescent smoking behavior from a developmental perspective. Using the fundamental form of growth curve analysis, this study will focus on the two parameters that reflect growth profile: the initial point of growth and the rate, or trajectory, of growth. A longitudinal data set obtained from a school-based smoking prevention program developed for adolescents is used. Two common assumptions on growth trajectories of smoking behavior among adolescents are considered in this paper: the linear growth trajectories and curvilinear, or quadratic, growth trajectories. The linear growth assumption models a monotonic increase on smoking behavior while the curvilinear assumption hypothesizes that smoking behavior among adolescents increases at a faster pace and then levels off. Using school as the unit of analysis, the outcome variable is school prevalence of cigarette use in the last month. Schools were observed repeatedly at five occasions. Two variables available at the school level, intervention conditions (program or control) and school types (public or private), are used to investigate their impacts on the differences in growth trajectory.

Measuring growth has been a very fascinating challenge for social scientists (Bock & Tissen, 1980; McArdle & Aber, 1990; Meredith & Tisak, 1990; Rogosa, Brandt & Zimowski, 1982; Rogosa & Willet, 1985; Willet, 1988). To better understand individual change, or growth profile, it is necessary to include time in a model. An approach that includes time in the model can be regarded as a type of growth profile analysis. Growth curve models have various traditions in broad areas, such as biostatistics (Laird & Ware, 1982; Liang & Zeger, 1986; Rao, 1958; Zeger & Liang, 1986), educational statistics (Bryk & Raudenbush, 1992; Burstein, 1980; Goldstein, 1987; Rogosa & Willet, 1985), and psychometrics (McArdle & Epstein, 1987; Meredith & Tisak, 1990; Tucker, 1958).

A growth curve model usually considers repeated measures of an outcome behavior as a function of time and other measures. Two of the most frequently considered components in the investigation of growth profiles are initial status of the growth curve and the rate, or trajectory, of growth. Understanding systematic changes among these two growth components due to individual differences is critical. One approach to better understand how and why each adolescent develops different smoking behavior is to examine the influence of individual background variables on the growth trajectory of smoking behavior. It is important to find out what factors may affect some adolescents to have higher level of use than others at younger ages and what conditions may change the level of use as they get older. Furthermore, different groups of adolescents may show different growth profiles if a group level variable is expected to relate to the outcome variable. Longitudinal panel data are often analyzed to investigate long-term trends of growth.

The latent growth curve model (LGM) was developed as a method to represent development (Meredith & Tisak, 1990). The LGM treats repeated measures of individual behavior as a function of development. For example, the developmental change of smoking behavior among adolescents can be modeled as a function of age in the LGM. The longitudinal measures of smoking behavior can be modeled as a function of two factors: an underlying smoking behavior (that is, initial smoking status) and the developmental trajectory of smoking behavior. Furthermore, the two factors can in turn be considered as functions of other smoking-related behaviors. Information on both mean vector and covariance matrix of the variables is required by the LGM to examine growth profile.

Meredith and Tisak (1990) developed a simple two-curve latent curve model. Two exogenous latent factors, ξ_1 and ξ_2, are used in the model. The LGM approach with a linear growth assumption can be expressed as:

$$y_{ij} = \lambda_{0i} \ \eta_{0j} + \lambda_{1i} \ \eta_{1j} + \varepsilon_{ij} \ , \qquad (1)$$

$$\eta_{0j} = \upsilon_0 + \gamma_{01} \ \xi_{1j} + \gamma_{02} \ \xi_{2j} + \xi_{0j} \ , \qquad (2)$$

$$\eta_{1j} = \upsilon_1 + \gamma_{11} \ \xi_{1j} + \gamma_{12} \ \xi_{2j} + \xi_{1j} \ , \qquad (3)$$

Equations 1,2, and 3 are mean and covariance structure equations. The first equation represents a measurement model and the latter two represent regressions among latent variables. The y_{ij} refers to measure of individual j at time i and is predicted by η_{0j} and η_{1j}. Further, η_{0j} and η_{1j} are the underlying factors representing the initial status and linear growth trajectory, respectively. The η_{0j} and η_{1j} factors with υ_0 and υ_1 as their corresponding intercepts are predicted by ξ_{1j} and ξ_{2j}, with residuals ζ_{0j} and ζ_{1j}, respectively. Typical structural equation model assumptions are made, e.g., γ's are regression weights, and ξ's are normally distributed with mean μ and variance Ψ. Considered as a random-effects model, random-effects are represented by the variances of ζ_{0j}, ζ_{1j}, and ε_{ij} which are residual variances of standard structural equation model. The measurement error variances (ε_{ij}) are assumed to be equal, or homogeneous, over time.

The LGM approach allows specification of growth, which is more complicated than just a linear increase. With a curvilinear growth assumption, a quadratic term of time needs to be added to Equation 1:

$$y_{ij} = \lambda_{0i}\ \eta_{0j} + \lambda_{1i}\ \eta_{1j} + \lambda_{2i}\ \eta_{2j} + \varepsilon ij\ , \tag{4}$$

The η_{2j} is added as another latent variable to represent the curvilinear growth trajectory. The quadratic assumption is made by fixing λ_{2i} at a known constant, say i^2 where i is the time of measurement. The new factor, η_{2j}, is regressed on the explanatory variables, ξ_{1j} and ξ_{2j}:

$$\eta_{2j} = \upsilon_2 + \lambda_{21}\ \xi_{1j} + \gamma_{22}\ \xi_{2j} + \zeta_{2j}\ , \tag{5}$$

where a new residual ζ_{2j}, also considered random-effect, is introduced as is typical in structural equation model.

I. Method

Longitudinal data obtained from a smoking prevention program were used in this study. A total of 50 middle schools (23 control and 27 program schools) in mid-western area of the US were randomly assigned to a health education program as usual control group or a smoking prevention intervention program as the program group. A total of 2,779 students who started at the seventh grade were surveyed at the baseline wave. Four follow-ups were conducted with the first being six months after baseline, and then one year apart for the other three follow-ups. Students at each of the five interviews were asked whether they had used any cigarettes in the last 30 days. School, which was the unit of experimental assignment, was also used as the unit of analysis. Prevalence of monthly cigarette use that is the percentage of students reporting any monthly cigarette use in each school was used as the outcome measure. Two school-level covariates were chosen to investigate their influences on the development of prevalence of cigarette use at the school level across time. These two conditioning variables were group membership (GROUP=0 for control group, and GROUP =1 for program group), and school type (TYPE=0 for private school, and TYPE=1 for public school).

Figure 1 presents the conceptual model using the LCA notations with the linear growth assumption. The repeated measures (i.e., Y_0 to Y_4) of school prevalence of monthly cigarette use were assumed to be affected by the two growth parameters defined as factors: the initial status (INTERCEPT, or η_0) and the growth trajectory (SLOPE, or η_1). The factor loadings associated with initial status, or λ_0's, were all fixed at 1, while those associated with slope, or λ_1's, were fixed at the value to reflect the time point at which the measure was obtained. It is important to appropriately reflect the distance of the time of follow-ups from the baseline. In this study the measurement points were not equally spaced. To more accurately represent this spacing of measurement, the λ_1's was defined at 0 for baseline or 1, 3, 5, and 7 for the four follow-ups, respectively, since the first follow-up was only six months after baseline and the other three follow-ups were then one year apart. Each unit of increment in time, therefore, represents six months apart. Figure 1 also includes the constant of *1*. Because a regression on a constant is an intercept, any covariates (such as GROUP and TYPE) or factors (such as INTERCEPT and SLOPE) with a path from the diamond indicate that an intercept term has been specified as a free parameter. Both INTERCEPT and SLOPE factors were further assumed to be influenced by the two school-level covariates: ξ_1 and ξ_2 which are GROUP and TYPE, respectively, after being adjusted by their corresponding means. Finally, the variances of measurement errors, are assumed to be homogeneous across time, i.e., $\sigma_2(\varepsilon_0) = \cdots = \sigma_2(\varepsilon_4)$. With the quadratic growth curve assumption, another SLOPE factor should be added to represent the quadratic term. The factor loadings for SLOPE2 (see λ_{2i} in Equation 4) will be fixed at 0, 1, 9, 25, and 49, respectively.

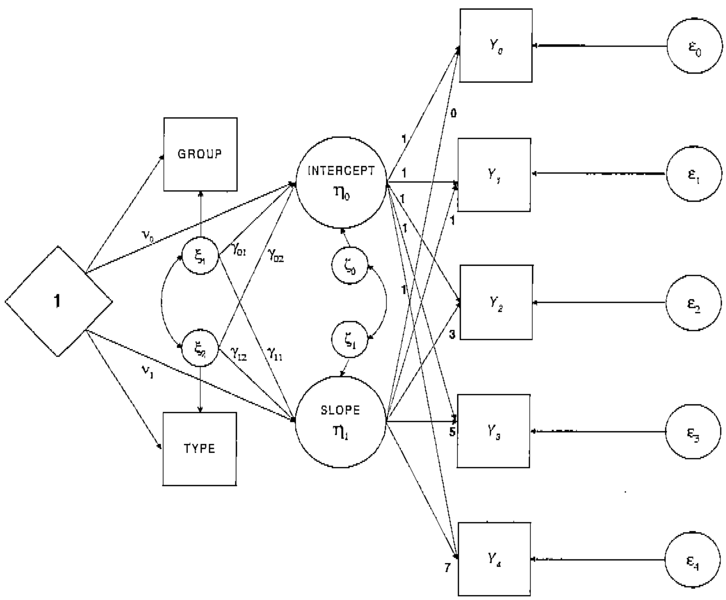

Figure1. the latent Curve Model

It further should be noted that the growth trajectory in the LGM approach proposed by Meredith and Tisak (1990) is not limited to linear or polynomial growth assumptions. Their approach is very general and allows some of the factor loadings associated with SLOPE to be free parameters to reflect relative growth trajectories across time. For the purpose of model identification and interpretation, the factor loading at the baseline is usually set at 0, i.e., no growth is assumed, and the factor loading at first follow-up is set at 1 as a reference. The estimates of loadings associated with the subsequent follow-ups, therefore, indicate the relative growth of each follow-up compared to that at the first follow-up.

II. Results

Means and standard deviations of prevalence of monthly cigarette use across all five waves of observation are summarized in Table 1. The prevalences are also reported by the different categories of each of the two covariates: GROUP and TYPE.

Table 1. Mean Prevalence of Cigarette Monthly Use by Group and School Type[a]

Cigarette Monthly Use	Wave 0	Wave 1	Wave 2	Wave 3	Wave 4
Total (N=50)	10.98 (8.08)	14.96 (11.33)	19.02 (10.62)	23.56 (8.24)	26.69 (12.48)
GROUP					
Control (N=23)	11.15 (8.78)	17.61 (13.11)	20.66 (10.25)	24.36 (7.72)	30.22 (14.07)
Program (N=27)	10.85 (7.60)	12.70 (9.23)	17.63 (10.93)	22.89 (8.74)	23.68 (10.27)
TYPE					
Private (N=28)	8.16 (8.19)	10.68 (11.09)	16.09 (11.44)	23.39 (9.73)	27.68 (15.49)
Public (N=22)	14.59 (6.46)	20.41 (9.28)	22.75 (8.31)	23.79 (6.05)	25.43 (7.21)
TYPE by GROUP					
Control-Private (N=12)	7.84 (9.87)	13.23 (14.95)	19.09 (11.81)	25.13 (10.20)	32.37 (18.78)
Control-Public (N=11)	14.76 (5.92)	22.39 (9.17)	22.36 (8.46)	23.52 (3.92)	27.87 (6.00)
Program-Private (N=16)	8.40 (7.02)	8.76 (6.95)	13.84 (10.98)	22.08 (9.48)	24.16 (11.92)
Program-Public (N=11)	14.42 (7.24)	18.43 (9.39)	23.14 (8.55)	24.05 (7.83)	22.98 (7.75)

a. Standard deviations are reported in parentheses.

Results obtained from the LGM model with the linear growth curve assumption is reported in the Table 2.

Table 2. Parameter estimates from LGM with linear growth curve

Parameter	Estimate	Standard Error
v_0	12.01	(1.38) **
γ_{01}	-1.13	(2.40)
γ_{02}	9.11	(2.41) **
γ_{10}	2.19	(0.25) **
γ_{11}	-0.57	(0.43)
γ_{12}	-1.60	(0.43) **
$\sigma2(\xi0)$	50.35	(14.59) **
$\sigma2(\xi1)$	1.05	(0.48)+
$\sigma(\xi0, \xi1)$	-2.08	(2.07)
$\sigma2(\varepsilon)$	40.74	(4.75) **
		X^2_{20}=50.44
		$p < 0.01$

+. Significant at .10 level; *. Significant at .05 level; **. Significant at .01 level.

Because of the definition of GROUP and TYPE variables in the school level model, the reference schools in this study are private schools in the control group. Under the linear growth assumption, the LGM results indicated that the average school prevalence of monthly cigarette use among the private schools in the control group at the baseline is 12.02%, and increases by 2.19% at each 6 month. Controlling for school type (TYPE), program schools are 1.13% lower in prevalence of monthly cigarette use than the control group at the baseline. And the growth rate of monthly cigarette use at each 6-month period in the program schools is 0.57% lower than that of the control schools. With GROUP membership controlled, public schools are 9.11% higher in prevalence of monthly cigarette use than private schools. Compared to the private schools, the growth rate significantly dropped by 1.60% for the public schools at each 6-month period. The goodness-of-fit 2 test statistic obtained from the LGM indicated that the models with linear growth do not appropriately fit the data. In other words, the hypothesis that growth rates of monthly cigarette use monotonically increase across time is not acceptable.

Results obtained from the LGM approach incorporating the quadratic growth curve assumption are summarized in Table 3. Although the X^2 test statistic of the LGM reported at the bottom of the table indicated that the quadratic growth curve model still does not fit the data, it is substantially better than the linear LGM. The positive estimates of regression coefficients associated with η_1 and the negative estimates of regression coefficients associated with η_2 indicated that the growth rate in general increases at a faster pace at the beginning, then at a slower pace, and levels off subsequently. This pattern seems to offer a better understanding of the growth profile of monthly cigarette use among adolescents.

Table 3. Parameter estimates from LGM with quadratic growth curve

Parameter	Estimate	Standard Error
ν_0	11.36	(1.27) **
$\gamma 01$	-1.73	(2.26)
$\gamma 02$	7.82	(2.27) **
$\gamma 10$	3.05	(0.59) **
$\gamma 11$	0.20	(1.18)
$\gamma 12$	0.06	(1.18)
$\gamma 20$	-0.12	(0.10)
$\gamma 21$	-0.11	(0.19)
$\gamma 22$	-0.24	(0.19)
$\sigma^2(\zeta 0)$	39.34	(13.16) **
$\sigma^2(\zeta 1]$	3.75	(3.94)
$\sigma^2(\zeta 2)$	0.19	(0.10)
$\sigma(\zeta 0, \zeta 1)$	6.21	(5.10)
$\sigma(\zeta 0, \zeta 2)$	-0.95	(0.79)
$\sigma(\zeta 0, \zeta 2)$	-0.83	(0.60)
$\sigma^2(\varepsilon)$	31.67	(4.52) **
		X^2_{14}= 26.62
		p = 0.02

+. Significant at .10 level; *. Significant at .05 level; **. Significant at .01 level.

There is a sharp increase in prevalence at the first follow-up for each category of schools. The private schools in both control and program groups started with lower prevalence rates of monthly cigarette use than the public schools. However, the growth trajectories of monthly cigarette use for the private schools monotonically increases over time; while that for the public schools, on the other hand, seems to have reached a plateau and flattens out after the first follow-up (Time 1). The prevalence rates for the public schools, therefore, become lower than those for the private schools. Public schools show higher percentages of use than the private schools at baseline. They also demonstrate a larger increase in monthly cigarette use than the private schools at the first follow-up. However, the growth rate for public schools seems to be smaller than that of the private schools after the first follow-up in the seventh grade. Although not significant, the program schools not only show a smaller rate of increase in cigarettes use than the control schools, and the gap increases across time.

III. Discussion

In this study, we reported four time point follow-up effects of a school-based prevention program on decreasing cigarette use among adolescents. It is worthwhile to note that the program group consistently demonstrated greater reductions in cigarette use across all follow-ups. The results indicated that the school-based intervention program had prevention effects, reaching the risk population of adolescents. The study demonstrated that the substance use prevention program was able to reach and positively affect adolescents. However, we need to exert further endeavor to know if a prevention program has an impact on those who have already begun to experiment with substance, since substance use at any given point in time is the strongest risk factor for later substance use. Future prevention studies should investigate the potential effects of prevention strategies on students at various levels of risk for substance use.

The general findings acquired from this study might be applied to the population of Korean adolescents. A school-based prevention program for decreasing cigarette use among adolescents may have effects on Korean population of adolescents in a similar direction. However, there is the chance that the shapes of growth trajectory are slightly different since sociocultural factors affect the onset and the developmental route of substance use in adolescence. It may be valuable to test the accelerated or decelerated growth trajectory of substance use among Korean adolescents with the nonlinear growth curve modeling, to get a refined understanding of the growth profile of adolescent cigarette use in Korea.

The early efforts at health education are essential for preventing adolescent substance use. Educational policy and intervention programs, as well as the research agenda of government need to be attuned to tracking the developmental profile of adolescent smoking behavior. A lot of research on adolescent substance use has used cross-sectional designs. It may lead to some problems in that the research results can not generalize across time points and they can not address the issue of the growth trajectory. The longitudinal design is important for prevention research. Acknowledging growth profile requires an awareness of the initial status and growth rate of adolescent smoking behavior.

Growth curve models have received increasing attention in social science research. The models are very appealing since they specifically model individual growth as a function of time and also can compare different growth rates across different groups. The latent growth curve model (LGM) deals with the two major characteristics of a growth profile, initial status and trajectory of growth curve, as latent factors, and models the repeated measures as a function of time and the latent factors. The LGM approach is somewhat complicated to set up and might have difficulties in obtaining convergence of the estimation procedure. However, it has the critical advantage in offering an overall goodness-of-fit test statistic to evaluate the appropriateness of the growth model. In addition the LGM is flexible to test various hypotheses. For example, the hypothesis with the relative growth rates proposed by Meredith and Tisak (1990) and the hypothesis of relaxing the assumption of homogeneity of the independence of random effect within individual, i. e., e_{ij}, can also be tested in LGM. The flexibility of LGM in testing homoscedasticity of measurement errors is also noted in Willet and Sayer (1994). Other more general advantages of the application of LGM approach to growth curve model can be found in Willet and Sayer (1994). Meredith and Tisak (1990) offered the concept of relative growth trajectories over time. Another flexible hypothesis testing by the LGM can also be conducted. Although the factor loadings in the LGM were usually fixed, they can be freed to reflect the relativity of specific measures compared to others.

Analyses conducted in a current study indicated that the LGM approach incorporating the quadratic growth curve assumption resulted in a better fit than the linear growth approach. The results showed that the growth rate in general increased at a faster pace at the beginning, then at a slower pace, and levels off subsequently. This pattern offers a refined understanding of the growth profile of monthly cigarette use among adolescents. The nonlinear growth curve modeling enables us to test the accelerated or decelerated growth trajectory of substance use. Therefore, the quadratic growth curve model may answer questions such as when adolescents may have steeper trajectories of substance use than at other time points.

Although researchers in the area of health education have tried to adopt covariance structure analysis, growth curve methodology implementing mean and covariance structure models have not been widely used in the study of adolescent smoking behavior. The approach will enable a broad range of researchers in the area of health education to earn the possibility for various analyses of growth profiles and developmental processes.

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