An Algorithm of Smoking Stages Assessment in Adolescents: A Validation Study Using the Latent Class Analysis Model

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ABSTRACT

Background: Notwithstanding the importance of smoking stages evaluation in adolescents, there is not an appropriate instrument for its measurement. This study aims to introduce an appropriate instrument for measurement of smoking stages in adolescents and to examine its validity using latent class analysis (LCA) model.

Methods: We designed an algorithm to measure the smoking stages. The relevancy and clarity of the algorithm was examined by experts and lay experts. We assessed the reliability of our algorithm using test-retest method. Moreover, using the LCA, we studied the validity of the stages measured by the designed algorithm in 4903 students (ages 14-19), who were randomly selected from grade 10 high school students in Tabriz (North-West of Iran).

Results: The algorithm content validity indicates high relevancy and clarity percentages. Intra-class correlation of 0.929 was found in the assessment of the reliability of smoking stages (9 stages) in 154 students within a two-week interval. The LCA model revealed nine interpretable classes ($G^2 = 0.051$, df $= 1$, $P = 0.821$) for the measurement of smoking stages. Examination of the smoking cessation stages in a sample of 218 students in the cessation stage demonstrated that the results for five classes could be interpreted ($G^2 = 0.001$, df $= 1$, $P = 0.975$).

Conclusions: The results suggested that this algorithm is clear, valid, and reliable.

Keywords: Adolescence, latent class analysis, reliability, smoking stages, validity

INTRODUCTION

The age of smoking onset is decreasing in both developed and developing countries[1] and most of the developed countries have implemented several policies in order to reduce smoking rates, more specifically among adolescents. This is because the age at initiation of cigarette smoking is one of the important determinants of tobacco dependence possibility, likelihood of smoking cessation, and the risk of unwilling

health consequences.[2-5] Many researchers have considered smoking behavior in adolescents as a transition or movement in some stages. Although, smoking onset and continuation are connected processes *per se*, in several studies it has been attempted to make this process into several stages so that primary and secondary prevention could be included. In the study conducted by Leventhal and Cleary in 1980s, it was suggested that smoking includes a complex continuum and in order to a person to be a smoker, different stages should be passed.[6] Subsequently, Flay *et al.* (1983)[7] and Stern *et al.* (1987)[8] accepted the multistage nature of smoking and proposed stages in a more sophisticated way. The initial stages then were shortened and described by Flay in 1993.[9] The following six stages were illustrated by Myhew *et al.* in 2000[10] using previous studies: percontemplation, contemplation or preparatory stage, tried or initiation, experimenter, regular, and established or daily smoker. Kremers *et al.* (2001 and 2004)[11,12] showed that nonsmokers in the percontemplation stage are not homogeneous and they can be included in three groups of committers, immotives, and progressives. The first group is sure that they will not smoke in the future. The second group does not plan to start smoking in the future (they do not have any definite program to do so), and the third group want to smoke, but not in the next six months. In addition, for the measurement of smoking stages and cessation, an algorithm has been proposed by Pallonen *et al.* (1998),[13] which is commonly used in the studies related to smoking stages in the adolescents. However, it is not a comprehensive method for the measurement of the smoking stages.

Understanding the process of adolescent smoking and identifying the predictors of passing through smoking stages are of great importance for policy makers in the development of effective strategies that prevent cigarette smoking. Notwithstanding the importance of smoking stages evaluation in adolescents, there is not an appropriate instrument for its measurement. This study aimed to design a suitable tool for this purpose and to assess its validity by latent class analysis (LCA) model, which is an appropriate technique for the evaluation of staging algorithm validity.[14-16] The LCA tests this hypothesis whether individual responses to the algorithm questions can be identified by smoking stage (latent variable) by examining the response patterns. Moreover, the validity and reliability of this algorithm was studied in this paper.

METHODS

Content validity

Considering the measurement algorithm for the smoking stages and cessation in adolescents proposed by Pallonen *et al.*,[13] and based on the smoking stages suggested by Myhew *et al.*[10] and Kremers *et al.*[12] study for the categorization of nonsmoker adolescents, a questionnaire was developed. Then, to evaluate its content validity, the designed questionnaire attached with an answer sheet for the opinions on relevancy and clarity of the algorithm were sent to the following people: 5 experts in the field of adolescence smoking (content expert), 6 experts on the questionnaire designing and methodology (methodology expert), 4 teachers and education experts in the field of student consulting and training and 5 alert students (lay expert). For the purpose of assessing the relevancy of the questionnaire, individuals were asked to answer the following question: "How much this question is associated with the measured parameter? In other words, how appropriate is this question?" The proposed answers were ranked as follows: 1-not suitable, 2-moderately suitable, 3-suitable and 4-completely suitable. For examining the clarity of the questionnaire, they were asked to answer the following question: "How clear is the meaning of this question?" The proposed answers were categorized as follows: 1-ambiguous, 2-moderately ambiguous, 3-clear and 4-completely clear. Answers 3 and 4 were considered as favorable and answers 1 and 2 were considered as unfavorable, then the relevancy and clarity percentages for two groups (experts and lay experts) were separately measured.

Reliability in the repeatability dimension

After gathering answer sheets and performing the modifications, the questionnaires were presented to 154 grade 10 high school students within a two-week interval so that its reliability could be determined in terms of repeatability dimension using ICC.

Construct validity using latent class analysis model

In order to evaluate the validity of the measured stages through the designed algorithm, the questionnaires were distributed to 4903 students in grade 10 with a mean age of 15.7 ± 0.73 years (range: 14-19) in Tabriz (a big city in North-West of Iran). They were sampled using a stratified method according to the number of students in each region, number of students in school and type of school followed by cluster sampling (each class was one cluster). The subjects were consisted of 2799 females and 2104 males.

To enhance the validity of student's self-reports, they were assured strict confidentiality of their responses and they could not be recognized by their answers. Also, they were informed about the voluntary nature of their participation in the study and their right to refuse or skip any questions.

The Ethics Committee of Tabriz University of Medical Sciences and Research Committee of the East Azarbaijan Province Education Organization approved the questionnaire. Verbal informed consent was obtained from students before completing the questionnaire.

The LCA was applied to evaluate the construct validity of the algorithm. The LCA is a latent categorical variable's model. The latent variable is not measured directly. Instead, it is measured indirectly by means of two or more observed variables. By analyzing given answers to the categorical observed variables, LCA classifies homogeneous individuals. It assumes that besides the measurement error, whether the correlation between observed variables could be justified by latent variable categories. The input data in LCA is response patterns and their frequencies. By various iterations for the number of identified classes of the latent variable and comparing the frequencies of the observed response patterns with the expected ones, the LCA determines the best model and calculates a statistics similar χ^2 called G^2. The distribution of G^2 is similar to the distribution of χ^2 if degree of freedom is less than 60. The significance of G^2 indicates the great difference between observed response pattern frequencies and the expected ones, as well as unfit of the model. In other words, it suggests that this number of the classes of latent variables is not fit for the observed response patterns.[17]

For performing LCA, four observable variables (i.e., indicators) were extracted from the questionnaire so that smoking stages could be studied as a latent variable. These indicators were as follows: smoking status with five categories, tendency to smoking in the future with five categories, smoking in the last month with two categories and smoking in the last week with two categories. Furthermore, to examine the validity of smoking cessation stages, four observable variables were extracted from the questionnaire: intention to quit smoking in the next 6 months with two categories, thinking about quitting in the next month with two categories, last time trying for smoking cessation with three categories, and smoking cessation status with three categories. The WinLTA (version 3.1) was used to perform LCA.[14]
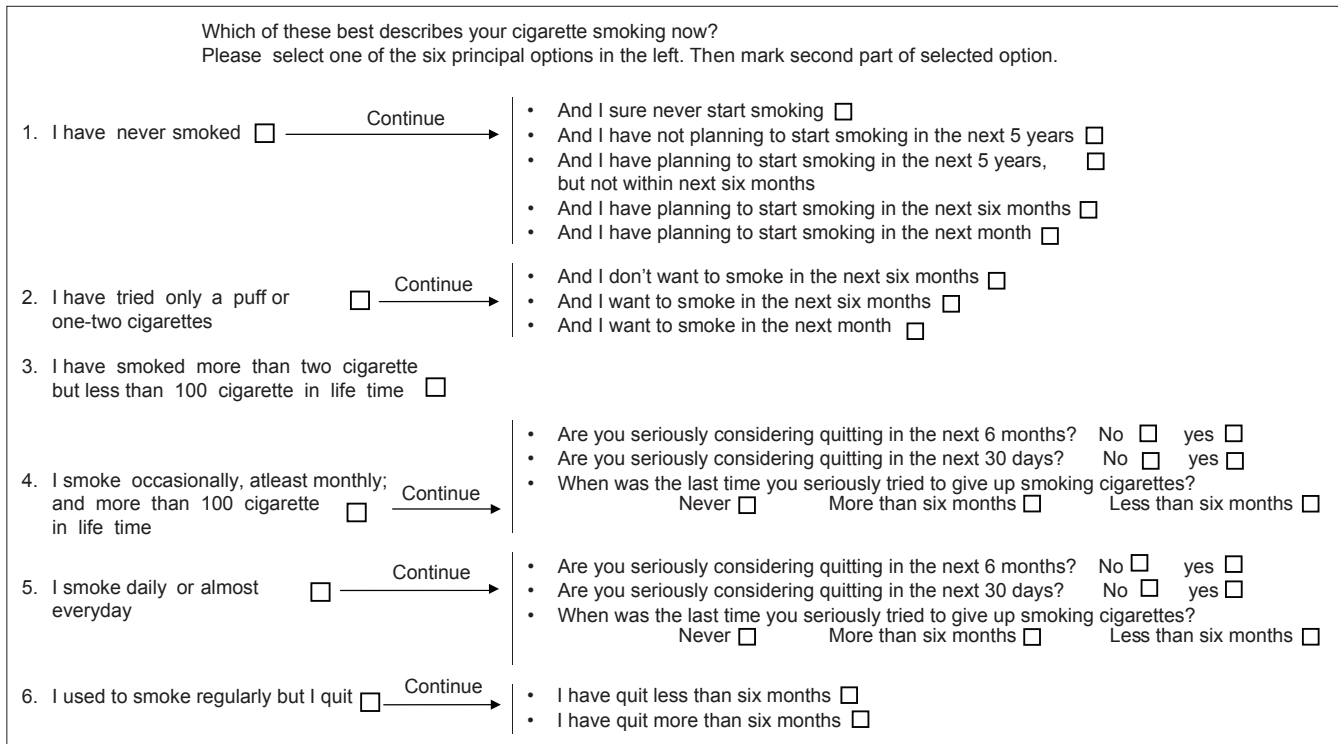
RESULTS

Algorithm

Final algorithm is presented in the Figure 1. First, the adolescents chose one of the main six options in the left. Then, they completed the second part of that option. In fact, this algorithm was constructed according to the algorithm proposed by Pallonen *et al.*,[13] Myhew *et al.*[10] and Kremers *et al.*[12] Smoking stages of the three above studies can be easily obtained by this algorithm.

Content validity

In the examining of content validity of this algorithm, the percentage of questionnaire relevancy for both groups was 100%. The clarity percent of the experts and lay experts were obtained 75% and 100%, respectively. Through assessment of smoking stages reliability [9 stages, Table 1], which was performed in 154 students with a two-week interval, the mean of intra-class correlation coefficient (ICC) of the questions was obtained 0.929 (CI 95%: 0.903-0.948).

Construct validity of algorithm

For identifying the smoking stages, by using LCA and considering two other questions (smoking in the last month and last week), validity of the algorithm was studied in 4834 students (69 subjects were excluded due to the lack of data on any of 5 observable variables), so that result of LCA model for the whole sample demonstrated

Figure 1: Algorithm for the acquisition and cessation stages

nine interpretable classes (G^2 = 0.051, df = 1, P = 0.821). Moreover, the obtained results of LCA with nine interpretable classes in females (n = 2796) (G^2 = 0.026, df = 1, P = 0.803) and males (n = 2038) were valid (G^2 = 0.003, df = 1, P = 0.956). These findings indicate that the model is excellent fit to the data. In other words, as it was shown in Table 1, both male and female students could be categorized in 9 classes (9 smoking stages) comprehensively based on the observed response patterns.

In order to determine the smoking cessation stages, validity of the algorithm was examined in 218 students. The LCA model demonstrated five interpretable valid classes (G^2 = 0.001, df = 1, P = 0.975). The results could be observed in Table 2. Similarly, these results indicate the excellent fitness of the model. That is, with respect to the observed response patterns for 4 observable variables related to smoking cessation, students could be categorized in 5 classes (5 stages of smoking cessation). Table 3 shows labels and descriptions of smoking stages, smoking cessation, and their measurements regarding to the algorithm.

DISCUSSION

This study designed an algorithm with high content validity and clarity. The reliability of the algorithm was also proved high within a two-week interval. Aveyard *et al.*[18] revealed that the algorithm proposed by Pallonen *et al.*[13] for smoking stages has a moderate reliability by analyzing two samples. It should be noted that most of their studied subjects, as well as previous studies conducted on smoking stages in adolescents who were the in the precontemplation stage.[16,19] In addition, in contrast to our study, they have not considered students in precontemplation stage in three groups which proposed by Kremers *et al.*[12] Therefore, the inclusion of majority of sample in one group and integrating three groups in one group cause the reliability to be increased. In our study, although we considered individuals in precontemplation stage in three separated groups, 65 percent of the sample was in the committer stage, which could increase the reliability.

The large sample size, the test-retest method for assessment of reliability and possibility of a change in smoking stage of adolescents in a two-week interval were strengths of this study in identifying the algorithm reliability.

Table 1: Probability of endorsing particular responses to the aqusision staging algorithm conditional upon stage membership

Stem and responses	Committer	Immotive	Progressive	Contemplator	Preparator	Tried	Experimenter	Regular	Established/ daily smoker
Stage distribution	0.777	0.022	0.012	0.002	0.004	0.117	0.027	0.014	0.025
Smoking status									
Never smoked	0.983	0.974	0.972	0.947	0.963	0.000	0.000	0.000	0.076
Tried only a puff or one-two cigarettes	0.009	0.011	0.011	0.022	0.016	0.984	0.009	0.089	0.106
Smoked more than two cigarette but less than 100 cigarette in life time	0.005	0.007	0.007	0.013	0.013	0.015	0.991	0.116	0.206
Smoke occasionally, at least monthly; and more than 100 cigarette in life	0.002	0.007	0.007	0.013	0.007	0.000	0.000	0.672	0.007
Smoke daily or almost every day	0.001	0.002	0.002	0.006	0.002	0.001	0.000	0.123	0.604
Intention to start smoking									
Sure never start smoking	0.997	0.011	0.001	0.010	0.002	0.201	0.202	0.243	0.889
Have not planning to start smoking in the next 5 years	0.002	0.980	0.010	0.008	0.003	0.200	0.200	0.189	0.000
Have planning to start smoking in the next 5 years, but not within next six months	0.001	0.008	0.985	0.012	0.005	0.200	0.200	0.188	0.000
Have planning to start smoking in the next six months	0.000	0.000	0.004	0.970	0.005	0.200	0.200	0.189	0.000
Have planning to start smoking in the next month	0.000	0.000	0.000	0.000	0.985	0.199	0.197	0.191	0.111
Smoked in the past month									
No	0.997	0.980	0.982	0.891	1.000	0.872	0.532	0.000	0.000
Yes	0.003	0.020	0.018	0.109	0.000	0.128	0.468	1.000	1.000
Smoked in the past week									
No	0.999	1.000	1.000	1.000	1.000	0.996	0.956	0.473	0.000
Yes	0.001	0.000	0.000	0.000	0.000	0.004	0.044	527	1.000

Table 2: Probability of endorsing particular responses to the cessation staging algorithm conditional upon stage membership (*n*=218)

Stem and responses	Precontemplation	Contemplation	Preparation	Action	Maintenance
Stage distribution	0.320	0.034	0.251	0.210	0.185
Intend to quit in next 6 months					
No	0.834	0.000	0.042	0.569	0.416
Yes	0.166	1.000	0.958	0.431	0.584
Intend to quit in next 30 days					
No	1.000	0.906	0.013	0.000	0.248
Yes	0.000	0.094	0.987	1.000	0.752
When was the last time you tried to give up smoking?					
Never	0.756	0.140	0.338	0.086	0.285
More than 6 months ago	0.000	0.286	0.008	0.473	0.282
Within 6 months	0.224	0.574	0.653	0.441	0.433
Have you completely stopped smoking?					
Never stopped	0.991	0.927	0.963	0.422	0.000
Within 6 months	0.005	0.064	0.028	0.563	0.020
More than 6 months ago	0.004	0.009	0.009	0.015	0.980

We used the LCA to examine if the adolescents in the smoking and cessation stages could be classified based on their responses to the stage algorithm. The results of the LCA suggested that response patterns

Table 3: Names, definations and measurements of smoking acquisition stages and cessation stages

Stages	Definition	Measurement in algorithm
Smoking acquisition stages		
Committer	Never smoked and Sure never start smoking	Selection of the first option on the left and first option on the right
Immotive	Never smoked and Have not planning to start smoking in the next 5 years	Selection of the first option on the left and second option on the right
Progressive	Never smoked and Have planning to start smoking in the next 5 years, but not within next six months	Selection of the first option on the left and third option on the right
Contemplator	Never smoked and Have planning to start smoking in the next six months	Selection of the first option on the left and fourth option on the right
Preparatory	Never smoked and Have planning to start smoking in the next month	Selection of the first option on the left and fifth option on the right
Tried	Tried only a puff or one-two cigarettes. Has not smoked in last Month	Selection of the second option on the left
Experimenter	Smoked more than two cigarettes but less than 100 cigarettes in life time. Has not smoked in last week and probably in last month	Selection of the third option on the left
Regular smoker	Smoke occasionally, at least monthly; And more than 100 cigarette in lifetime. has smoked probably in last week	Selection of the fourth option on the left
Established/ daily smoker	Smoke daily or almost every day. Hase smoked in last week	Selection of the fifth option on the left
Cessation stages		
Precontemplation	Not thinking about quitting in the next 6 months	Selection of the fourth or fifth option on the left and selection of "No" for first question or first option for third question on the right
Contemplation	Thinking about quitting in the next 6 months	Selection of the fourth or fifth option on the left and selection of "Yes" for first question and "No" for second question or second option for third question on the right
Preparation	Tried to quit within the last 6 months and thinking about quitting in the next 30 days	Selection of the fourth or fifth option on the left and selection of "Yes" for second question or third option for third question on the right
Action	Had quit smoking within the last 6 months	Selection of the sixth option on the left and first option on the right
Maintenance	Had quit smoking more than 6 months ago.	Selection of the sixth option on the left and second option on the right

to this algorithm highly corresponded with 9 smoking and 5 smoking cessation stages. As reported in Table 1, all of the smoking stages (9 stages) could be interpreted with respect to item-response probabilities. For example, in the first stage (committer) those who have never smoked with probability of 0.983, they were confident (0.997%) that they will never start smoking in the future, and those who have not smoked in the last month (0.997%) and they have not smoked in the last week (0.999). Another interesting example is the individuals in stage 5 (preparator)

who have never smoked (0.963%). They plan to start smoking in the next month with probability of 0.985 and they have smoked neither in the last month nor in the last week (100%).

It can be seen in Table 2 that according to item-response probabilities, smoking cessation stages can be interpreted. For example, individuals in the first stage (precontemplation) do not think about quitting in the next 6 months (0.834%) and they do not intend to quit smoking with 100% probability in the next month. They have never

tried to quit smoking (0.756%) and with. 991% probability have never stopped smoking completely. Another example in this table is the individuals in the second stage (contemplation) who 100% intend to quit smoking in the next 6 months and with 0.906% probability do not think about quitting in the next month and with 0.927% probability have never gave up smoking completely.

The validity of questionnaires for stage measuring and stage definition itself has been questioned.[20,21] It has been shown that the algorithm suggested by Pallonen *et al.*[13] to measure the smoking stages and cessation have theoretical and methodological problems.[20] Although the questions of this algorithm assess current behavior, quitting attempts, intention to change, and time since quitting, none of them are measured completely. Recently, in a study conducted by Guo *et al.*[16] other limitations have been raised. More specifically, they demonstrated that the transition across the stages is not sequential. In terms of staging assessment, even though our designed algorithm is comprehensive than the previous one, it does not measure behaviors and intentions comprehensively. Moreover, due to the cross-sectional nature of the present study, it cannot be claimed about the sequential nature of transition across the stages. Also, our method was confirmatory, not exploratory. It means that we did not want to study how individuals could be classified based on their responses to this algorithm, rather we aimed to study whether response patterns to this algorithm corresponds to our stages (9 stages for smoking and 5 stages for smoking cessation). The insignificant result of the LCA model is positive answer to this question. It should be mentioned that although all of the stages could be interpreted according to item-response probabilities, large number of the stages cause the non-significant result of the test.

CONCLUSIONS

Our findings showed that this algorithm is transparent, valid, and reliable. So this algorithm can be used for assessment of smoking stages in adolescents. However, the reliability was studied only in smoking stages and not for cessation stages. Thus, further studies are required to evaluate reliability of cessation stages. And a longitudinal study to assess the transition across the stages and their sequential nature are needed.

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