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BRIEF REPORT

E-cigarettes and health: segmentation of risk awareness with latent class analysis

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ABSTRACT

Electronic cigarette (e-cig) use, especially among young people, has become widespread. The aim of this study was to use Latent Class Analysis (LCA) to identify and categorize distinct groups of individuals based on their awareness of the health risks and characteristics of e-cigs. We administered a questionnaire to 83 participants, with an average age of 27.22 years, that included 83 questions on different aspects of e-cigs, including composition, health effects and risk perceptions. Only 23 questions were considered suitable for analysis. We found that the probability of belonging to the 'Low awareness' class is higher than the 'High awareness' class. We observed that there is a distinction between subjects with Low and High awareness about the risks of e-cigs, this is observed as the response probability of the 'High Awareness' class is greater than that of the 'Low Awareness' class. Among those who were surveyed, only 55.4% had a high awareness of the risks of e-cigs.

IMPACT STATEMENT: Our study shows a significant lack of awareness among young people regarding the risks associated with e-cigarettes.

KEY WORDS
Electronic cigarette (e-cig); awareness; health risks; Electronic Cigarette Attitudes Survey (ECAS); Adolescent E-Cigarette Consequences Questionnaire (AECQ); vaping.

INTRODUCTION

Electronic cigarettes (ECs or e-cigs) deliver nicotine by simulating traditional smoking, without burning tobacco (Electronic Nicotine Delivery Systems - ENDS). They also include pipes, cigars and electronic hookahs, as well as devices that heat tobacco without burning it (Heat-not-burn tobacco products). ECs generally consist of an atomizer that allows the so-called e-liquid to be raised to high temperatures, generating vapor ('vape'), which is then inhaled. The main components of the solution are solvents (propylene glycol, vegatal glycerin), variously associated with water, flavoring agents and nicotine. ECs were introduced to the market in Europe in 2006 and in the United States in 2007. According to data from the Global Youth Tobacco Survey, in Italy the prevalence of EC users in the 11-17 age group more than doubled from 2014 to 2018 (from 9.1% to 18.3%), with 2 times more use in males than females (1, 2). The use of e-cigs has spread widely in recent years as an alternative to traditional smoking, but awareness of the health risks associated with their use varies widely among individuals.

OBJECTIVES

The objective of this study was to investigate the knowledge, and the risk perceptions attributed to ECs among adolescents and their parents. Utilizing Latent Class Analysis (LCA), we aimed to identify and categorize distinct classes of individuals based on their awareness of health risks and characteristics of ECs by analyzing responses from an online questionnaire. LCA enables the detection of hidden patterns within the data, allowing for a more refined categorization of risk awareness levels among participants. This methodological approach facilitates a deeper understanding of how different segments of the population perceive the risks associated with ECs, which is crucial for developing targeted public health strategies and interventions. By uncovering these latent classes, the study contributes to the existing literature on ECs risk perception and provides valuable insights for policymakers and health professionals.

METHODS

From October 2023 to June 2024 an anonymous online questionnaire was administered to patients older than 12 years of age who were referred to the Pediatric Pneumology outpatient clinics of the Unit of Pediatrics at Pisa University Hospital and Buzzi Hospital in Milan, Italy, and their parents. The questionnaire consisted of three sections: i) knowledge about the risks related to ECs, ii) 'Adolescent E-Cigarette Consequences Questionnaire' (AECQ) for expectations about the use of ECs and iii) the 'Electronic Cigarette Attitudes Survey' (ECAS) related to attitude toward ECs.

In this study, LCA was employed to uncover underlying response patterns among individuals regarding health risk awareness and characteristics of e-cig. LCA is a statistical methodology that identifies unobserved subgroups within a population based on responses to observed variables, enabling the classification of respondents into distinct latent classes reflecting varying levels of awareness and perceptions.

The analysis utilized the poLCA package (3) in R statistical software version 4.4. The poLCA package estimates latent class models by maximizing the log-likelihood function with respect to the mixing proportions p_r and the class-conditional probabilities π_{jrk}. The log-likelihood function is defined as:

$$\ln L = \sum_{i,1}^{N} \ln \left(\sum_{r,1}^{R} p_r \prod_{j,1}^{J} \prod_{k,1}^{K} (\pi_{jrk})^{Y_{jrk}} \right)$$

Where J denotes polytomous categorical variables (manifest variables), each containing K_j possible outcomes for individuals $i=1,...,N$. The indicator Y_{jrk} equals 1 if respondent i selects the $k\text{-}th$ response to the $j\text{-}th$ variable, and 0 otherwise. The class-conditional probability π_{jrk} represents the likelihood that an observation in class $r=1,...,R$ produces the $k\text{-}th$ outcome on the $j\text{-}th$ variable, while p_r indicates the mixing proportions of the latent classes. The poLCA package leverages the iterative Expectation-Maximization algorithm to estimate the model parameters, allowing for the inclusion of cases with missing observations on the manifest variables. Within this framework, all associations among the included variables are attributed entirely to distinct subpopulations known as latent classes, wherein the variables are assumed to be independent (4).

Variable selection for LCA was performed to identify variables that contribute significant clustering information and to eliminate those that are redundant or uninformative.

LCA estimates two key parameters: the proportion of respondents in each latent class (prior probabilities of class membership) and the response probabilities within each class (item response probabilities). These parameters allow for the updating of prior probabilities into posterior probabilities for each respondent, given their observed response patterns (5). Consequently, respondents were probabilistically ranked and assigned to the most likely latent class.

Data were collected through a comprehensive questionnaire consisting of 83 questions addressing various aspects of e-cigs, including composition, health effects, and risk perception. Multiple LCA models were fitted by varying the number of latent classes (K) from one to five. The Bayesian Information Criterion (BIC) was employed to determine the optimal number of classes, with a lower BIC indicating a better model fit (6). For the optimal model, the estimated probabilities of positive responses were examined, and the classes were labeled accordingly.

Each subject's posterior probabilities of class membership were calculated, assigning them to the class with the highest probability. The overall classification accuracy was assessed by averaging the highest

Table 1. *Distribution of positive responses in the whole sample and by class of membership.*

Questions	All simple	All awareness	High awareness	p-value
1. The use of e-cigs can facilitate smoking cessation.	42 (50.6)	21 (63.6)	19 (43.2)	0.107
2. How familiar do you think you are with e-cigs?	54 (65.1)	16 (48.5)	34 (77.3)	0.015
3. Is the e-cigs safe in pregnancy?	47 (56.6)	14 (42.4)	28 (63.6)	0.105
4. Can the substances in e-cigs cause cancer and other disease?	67 (80.7)	25 (75.8)	37 (84.1)	0.396
5. Exposure to secondhand smoke from electronic cigarettes is not dangerous to children.	41 (49.4)	15 (45.5)	23 (52.3)	0.647
6. E-cigs are a device that aerosolizes flavored water, so they are safe: do you agree?	32 (38.6)	11 (33.3)	19 (43.2)	0.480
7. The long-term consequences of direct and passive exposure to e-cig aerosol have not been extensively studied. How much do you agree with this statement?	45 (54.2)	17 (51.5)	24 (54.5)	0.821
8. E-cigs deliver less nicotine than regular cigarettes.	57 (68.7)	20 (60.6)	33 (75.0)	0.218
9. In the long run, using an e-cig is cheaper than buying packs of regular (combustible) cigarettes. How much do you agree with this statement?	43 (51.8)	12 (36.4)	28 (63.6)	0.022
10. E-cig can be purchased by anyone, even children. How much do you agree with this statement?	23 (27.7)	6 (18.2)	15 (34.1)	0.195
11. To protect the health of the people I live with, it is enough to smoke on the terrace or outdoors. How much do you agree with this statement?	25 (30.1)	11(33.3)	14 (31.8)	1.000
12. Are you familiar with tobacco heating devices? (*e.g.*, IQOS)?	34 (41)	1 (3.0)	32 (72.7)	<0.001
13. Can tobacco warming devices (*e.g.*, IQOS) be addictive?	45 (54.2)	0 (0.0)	40 (90.9)	<0.001
14. Tobacco warming devices (*e.g.*, IQOS) can help smokers quit smoking.	35 (42.2)	1 (3.0)	33 (75.0)	<0.001
15. Tobacco heater devices (*e.g.*, IQOS) are less harmful to health than traditional cigarettes.	20 (24.1)	0 (0.0)	20 (45.5)	<0.001
16. Have you ever tried, or would you be willing to try to quit smoking ST and/or EC?	17 (20.5)	8 (24.2)	7 (15.9)	0.396
17. E-cigs help concentration.	34 (41)	11 (33.3)	21 (47.7)	0.247
18. E-cigs are bad for your lungs.	75 (90.4)	26 (78.8)	44 (100.0)	0.002
19. Most popular people smoke e-cigs.	59 (71.1)	24 (72.7)	30 (68.2)	0.802
20. A person has more control over the ingredients of an e-cigs (*e.g.*, nicotine content) thank a regular cigarette (fuel).	32 (38.6)	10 (30.3)	21 (47.7)	0.161
21. E-cigs are less harmful than regular (combustible) cigarettes.	28 (33.7)	15 (45.5)	8 (18.2)	0.013
22. The convenience of smoking e-cigs in more places (indoors) than regular (combustible) cigarettes are attractive.	28 (33.7)	14 (42.4)	13 (29.5)	0.335
23. In the long run, using e-cigs is cheaper than buying packs of regular (combustible) cigarettes.	66 (79.5)	30 (90.9)	31 (70.5)	0.045

posterior probabilities across all subjects, known as the assignment probability. Class-specific classification accuracies were also derived as conditional averages of these assignment probabilities, providing insight into the reliability of class assignments. Subjects with an assignment probability of at least 0.90 were considered to be classified with high certainty. Statistical analyses adhered to a significance threshold of $p \leq 0.05$.

RESULTS

Out of a sample of 83 participants with an average age of 27.22 years and 52% male, only 23 of the 83 survey questions were found to correctly identify the two knowledge profiles.

As depicted in **Table 1**, the probability of participants belonging to the 'Low Awareness' class is higher than that of the 'High Awareness' class, indicating a prevalent lack of awareness about the risks associated with e-cigarette use.

Figure 1 further highlights a distinction between subjects with differing awareness levels; specifically, the response probabilities of the high awareness group (represented by the green class) are lower than those of the low awareness group (represented by the pink class). The survey results revealed that only 55.4% of participants had a high awareness of the risks posed by e-cigarettes.

DISCUSSION

Our findings align with the recorded increase in current e-cigarette users and are consistent with previous studies conducted in other countries, which have also reported low levels of awareness regarding e-cigarette risks in both adolescents and their parents (7, 8). The long-term low awareness may lead to e-cigarette use and later in life to development of respiratory and cardiovascular problems, such as cough, wheeze, asthma and atherosclerosis, and to the increased risk of cancer (9). In addition, nicotine exposure in young age interferes with brain development and predisposes to having other addictions to substances in the future (10). We believe that low awareness among teens can trigger a vicious cycle, whereby teens risk using e-cigarettes, thus setting a bad example in turn for other young people. Through counseling services offered by pediatricians and primary care physicians, awareness of the risks and dangers of e-cigarette use can be markedly increased (11). In the field of public health, studies such as ours can persuade policymakers to invest more in awareness campaigns targeting the specific needs of young people. Educational interventions, like school-based programs, could help increasing awareness and reducing the prevalence of e-cigarette use in young people (12). One of the limitations of our study is that it studied a selected sample, as it consists of patients and their relatives referred to the outpatient pulmonology and allergology clinic. In fact, this sample is likely to be more sensitized to the issue of smoking due to the disease. Applying the LCA to a larger and more diverse sample may allow to organize a more targeted and detailed awareness campaign.

CONCLUSIONS

Our study reveals a significant lack of awareness among young people regarding the risks associated with vaping. The rapid proliferation of e-cig use among youth has reached epidemic proportions, thus necessitating immediate action to address this public health concern. Increased education and regulation are urgently needed to mitigate the potential long-term health consequences.

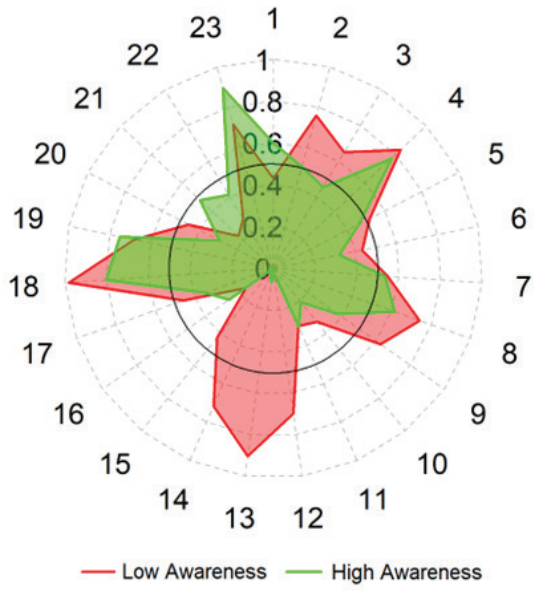

Figure 1. *Radar chart of the probability of belonging to the latent classes based on the affirmative answer to the question.*

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests

The Authors have declared no conflict of interests.

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Author contributions

The Authors confirm contribution to the manuscript as follows. Paper conception and design: GM, DME, RS, BG and BA; data collection: GM, RS, GG, BG and BA; data interpretation: PA, MG, RS, DME and GLS; draft manuscript preparation: GM, RS and PA; critical revision: LGS, GM and DME. All Authors reviewed the manuscript and approved its final version.

Ethical approval

Human studies and subjects

The study followed the ethical standards established in the Declaration of Helsinki.

Data sharing and data accessibility

Material and further inquiries can be directed to the Corresponding Author.

Publication ethics

Plagiarism

Authors declare no potentially overlapping publications with the content of this manuscript
and all original studies are cited as appropriate.

Data falsification and fabrication

All the data correspond to the real.

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