



# Medical students' awareness of e-cigarette use addiction

Wiedza studentów uczelni medycznych na temat nałogu używania e-papierosów

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## Abstract

**Introduction and Objective.** Since the introduction of electronic cigarettes (e-cigarettes), they have become popular in a short period of time, especially among youths. They are considered to be a healthier nicotine delivery system than cigarettes and supposed to be helpful in quitting smoking. However, studies have shown that they are a source of carcinogens such as, formaldehyde and acetaldehyde, polycyclic aromatic hydrocarbons, nitrosamines and heavy metals. The use of e-cigarettes can lead to the development of civilization diseases. The components of e-cigarette aerosol can also be harmful to people passively exposed to them.

**Materials and method.** A questionnaire survey was conducted in 2022–2023 in a group of 79 medical students (47 women and 32 men) aged 19–37 at the Medical University of Silesia in Katowice, south-west Poland.

**Results.** In the surveyed group of students, 28 reported smoking traditional cigarettes and 21 reported using e-cigarettes. Most e-cigarette smokers (52.4%) use less than 2ml of liquid per day. E-cigarettes are most often used at parties and in combination with alcohol. More than 90% of e-smokers smoke in rooms where non-smokers are present. Nearly 91% of respondents were passively exposed to e-cigarette vapour. When asked about toxic compounds formed during the process of liquid vaporization, nearly half of respondents (46.7%) answered 'don't know'. The second most common answer was 'carcinogenic compounds', and some mentioned heavy metals.

**Conclusions.** The vast majority of respondents were exposed to passive smoking of e-cigarettes. Many respondents had no knowledge of the harmful substances contained in e-cigarette smoke or gave incorrect answers.

## Key words

e-cigarettes, survey, secondhand exposure, carcinogens

## Streszczenie

**Wprowadzenie i cel pracy.** Od wprowadzenia na rynek papierosów elektronicznych (e-papierosów) stały się one w krótkim czasie niezwykle popularne, zwłaszcza wśród młodzieży. Skonstruowano je jako „zdrowsze” od tradycyjnych papierosów źródło nikotyny. Miały również być pomocne w rzuceniu palenia. Badania wykazały jednak, że są one źródłem rakotwórczych substancji takich jak formaldehyd i acetaldehyd, wielopierścieniowe węglowodory aromatyczne, nitrozoamin oraz metale ciężkie. Stosowanie e-papierosów może prowadzić do rozwoju chorób cywilizacyjnych. Produkty powstające podczas używania e-papierosów mogą być również szkodliwe dla biernych palaczy.

**Materiał i metoda.** W autorskim badaniu ankietowym, przeprowadzonym w latach 2022–2023, uczestniczyło 79 studentów (32 mężczyzn oraz 47 kobiet) kierunku lekarskiego Śląskiego Uniwersytetu Medycznego w Katowicach, w wieku 19–37 lat.

**Wyniki.** Spośród ankietowanych 28 osób zadeklarowało palenie tradycyjnych papierosów, a 21 – używanie e-papierosów. Większość palaczy e-papierosów (52,4%) zużywa mniej niż 2 ml liquidu na dobę. Ponad 90% badanych pali w pomieszczeniach, w których znajdują się osoby niepalące. Prawie 91% wszystkich ankietowanych było narażonych biernie na wyziewy z e-papierosów. Na pytanie o toksyczne związki powstające w procesie waporyzacji liquidu niemal połowa badanych (46,7%) odpowiedziała: „nie wiem”. Drugą najczęstszą odpowiedzią była: „związki kancerogenne” bez podania nazw, a kilka osób wspomniało o metalach ciężkich.

**Wnioski.** Zdecydowana większość ankietowanych była narażona na bierne palenie e-papierosów. Wielu ankietowanych nie posiadało wiedzy na temat szkodliwych substancji zawartych w dymie e-papierosowym lub udzielało odpowiedzi niepoprawnych.

## Słowa kluczowe

e-papierosy, badanie ankietowe, bierne narażenie, związki rakotwórcze

## INTRODUCTION

Since the introduction of e-cigarettes to the market in 2006 as a 'healthier' nicotine delivery system compared to traditional

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cigarettes [1, 2]. These products have become extremely popular in a short period of time, especially among young people [3, 4], and were also supposed to be helpful in quitting smoking [2, 5, 6]. Although e-cigarette aerosols contain less compounds of carcinogenic potential than cigarette smoke, there are still concerns regarding the risk for e-cigarette-induced cancer in humans [7, 8, 9].

Studies have shown that e-cigarettes are a source of harmful aldehydes [3, 10], such as formaldehyde which, according to the International Agency for Research on Cancer (IARC) [11], is an acetaldehyde, a compound possibly carcinogenic to humans, IARC Group 2B) [12], and acrolein, a compound probably carcinogenic to humans, Group 2A) [13]. During vaporization, these toxic substances are formed from chemicals (propylene glycol, glycerol and flavouring chemicals) contained in liquids. The aforementioned aldehydes can cause and intensify oxidative stress processes and have negative effects on cellular metabolism [2, 8, 14]. Damage of airway epithelium by formaldehyde is a known precursor to cancer development, and acetaldehyde and acrolein in e-cigarette aerosol may also intensify this effect [8].

The propylene glycol, glycerin and flavours present in liquids may, during the vaporization process, attach to the dental surface. This leads to the formation of biofilm that provides additional nutrients for pathogenic oral bacteria, such as *Streptococcus mutans* [15]. Dysbiosis among microbial of the oral cavity can lead to the development of periodontitis, caries, or even oral cancer [16].

The aerosols of e-cigarettes may also contain measurable levels of three- and four-ringed polycyclic aromatic hydrocarbons (PAHs), although in much lower amounts than conventional cigarette smoke [3, 17, 18]. They are formed as the result of thermal degradation of propylene glycol and glycerin. Some of the PAHs belongs to mutagenic and carcinogenic compounds.

In addition, some carcinogenic compounds from the nitrosamine group were detected in aerosol of e-cigarettes [10, 16, 19], including N-nitrosornicotine (*abbreviation*: NNN) and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (*abbreviation*: NNK) [9, 16], which have been classified by the IARC in Group 1 of carcinogenicity [20]. E-cigarettes aerosols can also contain small amounts of the heavy metals cadmium, lead, nickel, copper, chromium, and arsenic among others [3, 16]. Heavy metals mainly originate from the environment, fertilizers and plant protection products used during tobacco cultivation [21]. Other metals may come from the various components (e.g. heating elements) from which e-cigarettes are made [3]. Nickel, arsenic and cadmium compounds are classified by IARC as carcinogenic to humans (Group 1), and lead is classified in Group 2B – possibly carcinogenic to humans. [21]. Heavy metals also exhibit nephrotoxic, neurotoxic and haematotoxic effects [3, 10].

Due in part to the presence of cadmium in tobacco smoke, cigarette smoking has been found to increase the risk of toxic testicular damage, impaired testosterone synthesis and impaired male fertility [22]. Smoking traditional cigarettes significantly (50 times) increases the likelihood of adverse health effects, compared to non-smokers who are chronically exposed to heavy metals from the atmosphere [21]. Although the aerosol from e-cigarettes contains a 100 times lower concentration of heavy metals than cigarette smoke, it still amounts to over 0.1 ng / drag [3].

The results of an *in vitro* study shows that e-cigarettes condensate may promote the growth of breast cancer cells [23], and some animals' studies reveal that aerosols may impair DNA repair systems and induce the formation of DNA adducts [24]. The cancer-initiating and co-mutagenic effects of e-cigarette vapour was demonstrated in a rat lung model, where it was found that e-cigarettes caused an increase in oxygen free radical production and DNA oxidation [25].

A review of studies indicates that the risk of head and neck cancer remains lower in e-cigarettes users compared to tobacco smokers, although long-term study results are not yet available [26]. Furthermore, excessive exposure to reactive oxygen species significantly reduces male fertility due to damage to sperm cell membranes [22]. Also, the risk of infertility in women who smoke traditional cigarettes is higher than in women who do not smoke, and attempts to become pregnant take more time [27]. E-cigarettes are increasingly being chosen by women as a 'healthier' alternative way of smoking, but at the moment the issue of whether e-cigarettes are a safer addiction option for women who are pregnant, or trying to get pregnant, has not been fully investigated [28].

It has already been proven that exposure to propylene glycol and glycol ethers can increase the incidence of asthma [29, 30]. The risks associated with the aromas contained in the liquids is unknown, but some of them, such as diacetyl, can induce bronchitis [29, 30]. Other studies show a rise in the number of cases of the exogenous lipoid pneumonia due to usage of e-cigarettes [30, 31]. *In vivo* human studies have shown that intense inhalation of e-cigarette aerosols can dysregulate normal lung homeostasis in healthy individuals [32]. It has also been also reported that vapers are more likely to be infected by COVID-19 [29].

A recent review of the role of e-cigarettes in the pathogenesis of atherosclerosis shows that compounds such as propylene glycol, nicotine, flavourings and heavy metals can induce atherosclerosis through a mechanism of inflammation endothelial dysfunction and

radical oxygen species formation [33]. A review on the effects of electronic cigarette use on the development of metabolic syndrome found that they can affect glucose levels and the development of pre-diabetes, as well as increase the risk of obesity and hypertension [34].

Nicotine contained in liquids, exhibits strong psychological and physical dependence. Moreover, it disrupts intestinal function, contributes to a decrease in physical capacity, and some of its metabolites show carcinogenic effects [35]. Studies also confirm an increase in heart rate and blood pressure in e-cigarette smokers [3, 36], which can subsequently lead to myocardial ischemia [37]. These parameters are much higher when using liquids with nicotine, which stimulates the sympathetic nervous system, and consequently leads to the release of catecholamines [14].

E-cigarettes usage also includes the problem of secondhand exposure and its impact on the health of bystanders, which at the moment is scarcely explored. It is known that secondhand aerosol (SHA) from e-cigarette contains a number of toxic chemical compounds that are also found in e-cigarette liquids, such as propylene glycol, formaldehyde, acetaldehyde, nicotine or toluene, polycyclic hydrocarbons, tobacco-specific nitrosamines and heavy metals [38, 39, 40]. It has been shown that bystanders may absorb nicotine from e-cigarettes aerosols, and this exposure is lower or

comparable with secondhand tobacco smoke [41, 42].

One of the latest surveys on exposure to secondhand aerosol of e-cigarettes in indoor settings in selected European countries, revealed that approximately 16% of e-cigarettes non-users are exposed to SHA weekly [41]. Taking into account the growing knowledge of secondhand aerosol from e-cigarette content, and the fact that exposure to SHA may induce some harmful effects to bystanders, a better understanding of this phenomenon is crucial and necessary to develop and implement more adequate regulations regarding e-cigarette use in public places.

The aim of the study was to assess the observation of e-cigarettes usage and awareness of its potential harmful influence on health in a group of medicine students, i.e. young people with a special interest in human and public health issues.

## MATERIALS AND METHOD

A questionnaire survey was undertaken in 2022–2023 in a group of 79 students aged 19–37 at the Medical University of Silesia in Katowice, south west Poland. The survey included 31 sixth-year students and 48 second-year students who had just completed the facultative classes in the subject of food and environmental toxicology. Before handing-out the questionnaire, the purpose of the study was presented, participants were encouraged to answer honestly, and it was ensured that all questions were well understood. The questionnaire contained 17 questions: single-choice, multiple-choice and one open question. The survey included 4 questions on socio-demographic conditions, such as gender, age, year of study and place of residence, and 14 main research questions. Participation in the survey was voluntary and anonymous. Results were collected both on paper and as online questionnaire. Data were processed using Excel 2013.

## RESULTS

More women (n=47) than men (n=32) aged 19–37 took part in the survey. Among the respondents, 28 people (35.4%) reported smoking traditional cigarettes and 21 people (26.6%) reported using e-cigarettes. Most respondents (n=11; 52.4%) who declared using e-cigarettes smoked less than 2ml of liquid per day, while lower number (n=6; 28.6%) smoke 2–5ml (Fig. 1). The next survey question considered the amount of nicotine in the liquids. The results of are presented in the figure 2. Only 2 students (9.5% of total number of respondents who used e-cigarettes) reported the use of nicotine-free liquids (Fig. 2). The rest of the study group used liquids with nicotine concentrations in the range of 9–12 mg/ml (n=6; 28.6%) and 16–24 mg/ml (n=5; 23.8%).

As for the reasons of reaching for e-cigarettes, the 3 most common responses were: 'No unpleasant smell compared to traditional cigarettes' (n=13; 28.3%), 'Wide range of flavours' (n=10; 21.7%), and 'I was encouraged by friends' (n=9; 19.6%). When asked about the situation in which they most often use e-cigarettes, respondents answered: 'During entertainment, parties' (n=12; 25.5%), 'While consuming alcohol' (n=9; 19.1%), and 6 respondents (12.8%) reported that they smoke all day long (Figure 3). More than 90% of respondents (n=19) who declared using e-cigarettes, answered positively that

they smoked e-cigarettes in a indoor/ enclosed space where non-smokers were present.

On the other hand, 91% of all respondents (n=72) had been in situations where other people smoked e-cigarettes around them in a enclosed space. For the question 'Do you think e-cigarettes are healthier than traditional cigarettes', 31 students (39.2%) answered negatively, 18 students (22.8%) had no opinion, and 30 respondents (38%) answered positively. For an open question about toxic substances found in e-cigarette smoke, as many as 46.7% of respondents (n=37) answered 'don't know', 9.9% of students (n=9) wrote 'carcinogens', while only 6.6% (n=6) mentioned PAHs (Fig. 4).

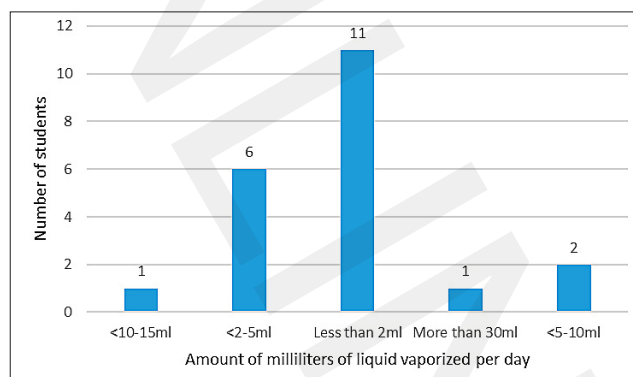


Figure 1. Amount of liquid vaporized per day by the study participants.

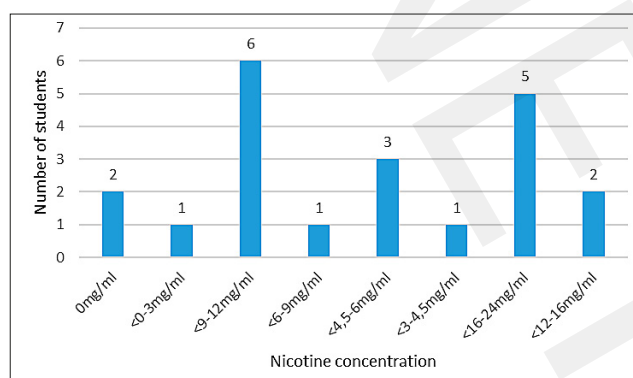


Figure 2. Nicotine concentration in liquid used by the study participants.

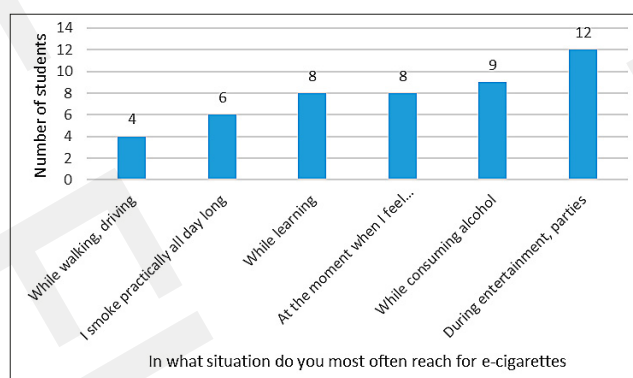


Figure 3. Situation in which respondents are most likely to use e-cigarettes

Table 1 compares the survey responses from respondents using e-cigarettes grouped by gender, age and year of study. The results indicate that the preferred amount of liquid vaporized per day was similar between men and women. Use of the largest amount of liquid per day (more than 30

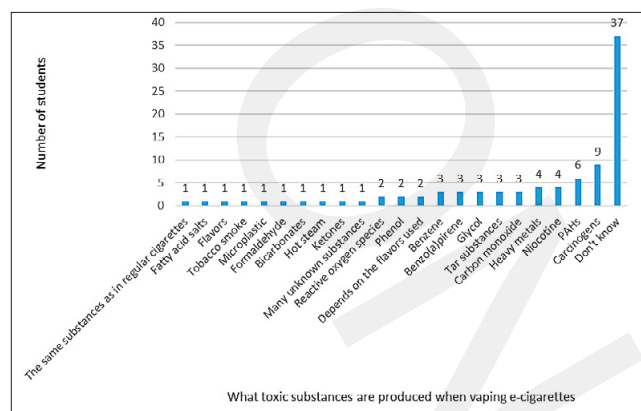


Figure 4. Respondents' answers to an open-ended question on toxic substances formed during vaping e-cigarettes

ml) was declared by one woman, a 6th year student. Nicotine concentrations in liquid used by men and women were also similar, although only the men (2 students in the 2nd year) used nicotine-free liquids. All women declared using nicotine liquids. Second-year students, and in general those aged 21–24, were more likely to use e-cigarettes while studying, under stress, while consuming alcohol, and during parties, compared to 6th-year students. To an open-ended question on toxic substances formed during vaping e-cigarettes, in the group of e-cigarettes users, more correct answers (PAHs, carcinogens, heavy metals) were obtained from 2nd year students than those from the 6th year, while the answer 'I don't know' was given by almost the same number of 2nd and 6th year students, including more women (9 students) than men (4 students).

Table 1. E-cigarettes users respondents' answers depending on gender, age and year of study

Type of question	Gender		Age (years)				Year of study	
	Women n=11	Men n=10	18–20 n=5	21–24 n=11	25–29 n=3	30 and over n=1	II n=13	VI n=8
Single-choice question	Amount of liquid vaporized per day							
Less than 2 ml	6	5	3	7	1	0	8	3
2–5 ml	2	4	1	3	1	0	3	3
5–10 ml	1	1	1	1	0	0	2	0
10–15 ml	1	0	0	0	1	0	0	1
More than 30 ml	1	0	0	0	0	1	0	1
Single-choice question	Nicotine concentration in liquid used by the study group participants							
0 mg/ml	0	2	1	1	0	0	2	0
0–3 mg/ml	0	1	0	1	0	0	1	0
3–4.5 mg/ml	1	0	0	0	1	0	0	1
4.5–6 mg/ml	2	1	1	1	1	0	2	1
6–9 mg/ml	1	0	0	1	0	0	0	1
9–12 mg/ml	3	3	2	3	1	0	4	2
12–16 mg/ml	1	1	1	1	0	0	2	0
16–24 mg/ml	3	2	0	3	1	1	2	3
Multiple-choice question	Situation in which respondents are most likely to use e-cigarettes							
While walking, driving	3	2	2	3	0	0	4	1
I smoke all day	3	3	2	1	3	0	2	4
While learning	5	3	3	4	0	1	6	2
When I feel stressed	5	4	1	7	1	0	6	3
While consuming alcohol	5	4	1	7	1	0	7	2
During entertainment	7	7	3	10	1	0	10	4
Multiple-choice question	Reasons of reaching for e-cigarettes							
No unpleasant scent compared to cigarettes	8	6	3	7	4	0	8	6
Wide range of flavors	6	5	4	5	2	0	7	4
Encouraged by friends	5	5	3	4	3	0	6	4
New trend	2	2	1	2	1	0	3	1
Media coverage of e-cigarettes as being healthier than „traditional” smoking	2	3	1	3	0	1	2	5
Lower costs compared to traditional smoking	0	2	2	0	0	0	2	0
Open question	What toxic substances are produced when vaping e-cigarettes?							
Heavy metals	0	1	1	0	0	0	1	0
Nicotine	0	0	0	0	0	0	0	0
PAHs	0	1	0	1	0	0	1	0
Carcinogens	2	1	0	3	0	0	3	0
I don't know	9	4	4	5	3	1	6	7
Carbon monoxide	0	1	0	1	0	0	1	0
Flavours	0	2	1	1	0	0	2	0
Glycerin/ Glycol	0	2	1	0	1	0	1	1

## DISCUSSION

In the last decade, e-cigarettes products have become popular, and the use of e-cigarette has definitely been increasing since it is promoted as a beneficial smoking cessation option, and an alternative nicotine delivery system containing no combustion by-products, and thereby simply less harmful than conventional cigarettes [3, 9]. The percentage of students who reported using e-cigarettes (26.6%) was similar to the results of a survey conducted several years ago on a large group (n=4032) of middle and high school students from central Poland. In that survey, 27.4% of respondents indicated that they had used e-cigarettes in the past month [43]. These results are also consistent with another survey conducted in Poland, in which current e-cigarette use was declared by about 30% of the teenage population [44].

The usage of e-cigarettes among young people is very popular and has greatly increased in recent years [44] because of the attraction of the novelty of the device, and the opinion that e-cigarettes are less harmful than conventional smoking [2, 3, 43, 45]. This was also confirmed by the results of the current survey in which 38% of respondents felt that e-cigarettes are healthier than traditional cigarettes, while as many as 23% of students had no opinion on the subject. This is definitely alarming, since youths are more susceptible to nicotine dependence than adults [35]. Moreover, it was proved that nicotine has adverse effects on brain development [46] and even passive exposure to e-cigarette emissions is associated with worsened mental health [47]. Nicotine is a highly addictive tobacco alkaloid and the increasing use of nicotine-containing devices like e-cigarettes by young people (mainly teenagers) who are not in the need of smoking cessation have no need to quit cigarette smoking may result in greater nicotine dependence in the future [40, 43].

The risk associated with e-cigarettes use still remains controversial from scientific as well as the public health point of view. Available studies indicate that vaping solutions and their emissions' products may contain much more than just nicotine [3, 6, 16, 18, 29]. They are also a source of harmful aldehydes or nitrosamines and many other chemical contaminants produced during vapour formation, presenting undefined potential health hazards to both e-cigarette users and bystanders [3, 19, 20, 48]. Despite increasingly frequent reports on social media about the presence of toxic constituents, the general public are not well informed about the potential serious or long-term risks of using e-cigarettes, or being exposed to SHA. The results of the presented study also confirm the problem because only a few respondents were able to name some of the toxic compounds formed during vaping e-cigarettes. Nearly half of the respondents (n=37; 46.8%) did not know any of the potential hazard compounds, or even the names of groups of compounds (e.g. aldehydes, carcinogens); some of them gave incorrect answers, e.g. fatty acids salts or bicarbonates. Among the toxic substances that can occur in e-cigarette smoke (isoprene, butanone, benzene, toluene, styrene, heavy metals, benzoic acid, benzaldehyde, acetaldehyde, formaldehyde, acrolein, PAHs, benzo(a)pyrene (BaP), tobacco-specific nitrosamines) [6, 40, 49], only a few of students mentioned PAHs, benzo(a)pyrene (BaP), formaldehyde, benzene, or heavy metals.

Another emerging issue regarding e-cigarettes is secondhand exposure to e-cigarette aerosols. Many

questions about the potential health risk posed by the use of e-cigarettes indoors, and its influence on bystanders, also remain unanswered [41, 42]. As the liquid is heated, the above-mentioned harmful compounds formed can enter the body of passive smokers [50]. Studies have shown higher concentrations of nicotine metabolites in the urine of people exposed to e-cigarette passive smoking, compared to a control group of non-smokers [41, 51, 52]. Moreover, researchers found detectable concentrations of tobacco specific carcinogenic nitrosamines in the urine and saliva of non-smokers passively exposed to SHA [52, 53]. It was found that the secondhand aerosol from e-cigarette may cause acute reduced lung function and exacerbate asthma symptoms [30, 54, 55].

The potential level of exposure to SHA in public places and workplaces may range from 4% – 38% in many countries, which shows significant differences between countries [39]. In Poland, this rate is 12% [39], and is definitely connected with the differences in overall e-cigarette use prevalence among countries, and general regulations for the ban of the use of e-cigarette in public places. However, the results obtained in the present study among young people – medical students, indicate that the vast majority of respondents (about 90%) were exposed to passive smoking of e-cigarettes, or used them themselves in the presence of others in enclosed spaces. The results of a study conducted among obstetrics students in Italy where special programme was implemented on tobacco smoking and e-cigarettes [56], showed that the majority of the students (87%) believed that the active smoking of e-cigarettes was harmful to health, and 82% of respondents stated that passive smoking was also harmful. Nevertheless, 72% of the students surveyed said they usually spent their free time with smokers. Most (63%) of respondents were exposed only outdoors, but 19% were also exposed indoors, mainly at home. It seems that even high health awareness among young people, based on their interests and choice of field of study, does not translate into behaviour to avoid exposure to e-cigarette components which are harmful to their health and the people around them.

## CONCLUSIONS

E-cigarettes have been recognized for years as a healthier substitute for traditional cigarettes. Their users often use them in the company of others, even indoors. Awareness of the harmfulness of the e-cigarette aerosol is not bringing about any change in social behavior, even among young people studying medicine. Therefore, it would seem advisable that the knowledge concerning the harmfulness effect of e-cigarette usage should be disseminated especially among young people who are the largest group of e-cigarette users. Improving knowledge of the toxic compounds contained in e-cigarette smoke should lead to the promoting of health-seeking behaviour, and increasing public awareness of possible complications and the risk of developing civilization diseases, such as cancer or cardiac ischemia, and could lead to the introduction of regulations banning e-cigarette smoking in public spaces in the future.

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