

E-cigarettes – their use and harmfulness. A brief summary of current scientific knowledge

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The consumption of e-cigarettes has rapidly increased in the last years, both worldwide and in Poland, especially among adolescents and youth. Many e-cigarette users also smoke conventional cigarettes ("dual use"). Some researchers argue that e-cigarette vaping, where tobacco burning seems to be eliminated, significantly reduces the number and content of toxic substances when compared to combustible tobacco products. They also underline that consumption of less harmful tobacco and nicotine products can substantially reduce the health consequences of tobacco smoking when the cigarette smoking would be substituted by the e-cigarette use. However, the number of studies that prove negative health consequences of e-cigarette use is steadily increasing. Many carcinogenic, cardiovascular and pulmonary toxic compounds were found in e-cigarettes and, dependently on the patterns of e-cigarette use, their content may increase to the level observed for cigarette smoking. Studies prove that dual use of e-cigarettes and manufactured cigarettes is more risky than cigarette smoking. Therefore, there is an urgent need to regulate e-cigarettes as strictly as tobacco products.

Key words: e-cigarettes, use, harmfulness

There is currently a debate worldwide about whether the increasing consumption of e-cigarettes in many countries may replace the epidemic of traditional cigarette smoking and whether it may reduce the health effects of tobacco smoking.

The e-cigarette consumption and prevalence of e-cigarette use

In the last decade, the global market of e-cigarettes has grown rapidly. According to the World Health Organization (WHO) data, the number of e-cigarette users has increased worldwide from 7 million in 2011 to 68–82 million in 2021 [1]. The fastest increase of e-cigarette consumption has been noticed on the market of so-called disposable e-cigarettes that are no-rechargeable and no-refillable products designed to be used once only. Between 2018 and 2022, the market of disposable cigarettes increased approximately 116%, re-

aching 22% of the whole global e-cigarette market [2]. In Poland, since e-cigarettes were registered on Polish market, the number of all e-cigarettes consumers rose to 1.5 million and number of disposable e-cigarettes might reach even 100 million sticks in 2023, with over 200% increase since 2022 [3].

Although Poles belong to one of the biggest consumers of e-cigarettes in Europe, the prevalence of e-cigarette use among Polish adults is still much lower than prevalence of cigarette smoking and tends to steadily decline in last years. Results of the 2021 Public Opinion Research Center (Centrum Badania Opinii Społecznej – CBOS) nation-wide survey shows that prevalence of current regular e-cigarette users does not exceed 1% of the total Polish adult population (aged 18 and over) while the proportion of current regular cigarettes smokers among adult Poles reaches 25.1% [4]. However, it should be noted that high proportion of European current e-cigarette

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users (over 50%), including Poles, also simultaneously smoke conventional cigarettes ("dual use") [5, 6].

A much more serious public health problem is the rapid increase in e-cigarette use among adolescents [7], mainly the use of disposable e-cigarettes that are cheaper than other e-cigarettes, aggressively promoted and easily accessible in Internet, and frequently not equipped with any health warnings or information on smoking cessation services [8, 9]. The results of the latest Global Youth Tobacco Survey (GYTS), conducted in Poland in 2022 on nation-wide random sample of 13–15 years old schoolchildren, indicate that 42% of them have ever used e-cigarettes and 22% currently use these products that is over two times bigger proportion when compared with students smoking cigarettes (12%) [10]. Based on results of GYTS and other studies, WHO indicates on high level of dual use of e-cigarettes and smoking of manufactured cigarettes among youth but simultaneously estimates that one third of adolescents who use e-cigarettes have never smoked a conventional cigarette [1, 11, 12]. It shows that e-cigarettes use may serve as a gate to experimentation and, later on, to regular use of tobacco products, including cigarette smoking and contribute to perpetuating the global tobacco epidemic.

The harmfulness of e-cigarette use

Proponents of e-cigarettes argue that e-cigarette vaping, where tobacco burning seems to be eliminated, significantly reduces the number and content of toxic substances when compared to combustible tobacco products [13]. Based on this argument, the 2015 Public Health England report concluded that e-cigarettes are 95% safer than combustible tobacco products, especially cigarettes [14]. The "harm reduction" approach suggests that replacement of the epidemic of cigarette smoking with an epidemic of "smoke-free" e-cigarette use may substantially reduce a number of smoking-attributable diseases, including lung cancer, chronic obstructive pulmonary disease, myocardial infarction or stroke, and, consequently, improve public health [15; see there a debate on the approach].

According to the 2018 US National Academies of Science, Engineering and Medicine's report and recent WHO reports on electronic cigarettes, summarizing the results of the latest reviews of chemical, clinical and epidemiological studies, abovementioned conclusions are inaccurate and based on insufficient evidence [1, 8, 11, 16]. It is pointed out that only a limited range of e-cigarette liquids have been studied so far, and the level of their toxicity varies significantly in individual studies and is dependent on user and device characteristics [11]. It is also emphasized that toxicological monitoring of e-cigarettes is currently very challenging because they are not a subject to as strict regulations in this regard as conventional combustible tobacco products and is too early to fully evaluate the long-term health effects of e-cigarette, in particular for cancer [1, 17].

Nicotine, that is highly psychoactive and addictive substance, is present in e-cigarette liquid in high doses [9, 18]. Prolonged, uninterrupted inhalation of high doses of nicotine may contribute to the risk of poisoning and immediate intoxication [19]. The biggest risk of nicotine intoxication concerns users of disposable e-cigarettes where permitted content of nicotine in e-cigarette liquid (20 mg/ml) is often doubled and the number of puffs (700 to 800) per e-cigarette is the highest [3, 9]. Then an equivalent of nicotine absorbed from e-cigarette equals smoking of 2 to 3 packs of cigarettes per one time unit [11]. High doses of nicotine in e-cigarettes also increase a psychoactive potential of nicotine and impede the effective treatment of nicotine dependence [18]. The higher amount of nicotine in e-cigarettes depends on electrical power generated in the device; increasing the power output of the e-cigarette battery from 3 to 7.5 W may raise the nicotine yield up to five times [8].

According to WHO estimates, e-cigarettes contain the largest number of flavors of all nicotine and tobacco products, especially in disposable e-cigarette devices [8]. Many flavors appeal to young people and some flavors, for example menthol, increase and accelerate nicotine absorption and mask the harshness of nicotine [1, 8, 18]. Flavors contained in e-cigarettes contribute to e-cigarette use initiation, help e-cigarette user switch from experimentation to regular use and from e-cigarette use to cigarette smoking and, finally, make successful quit attempt more difficult [20].

Epidemiological studies show that nicotine may negatively influence on the psychoneurological development of fetus, newborn and small child, especially when woman continue the use of tobacco or nicotine products during pregnancy [1]. It may affect the development of children's and adolescents' brain (changes in so-called nicotine receptors) and increase the risk of nicotine use and dependence during late adolescence or adulthood [19]. There is also an evidence that e-cigarettes are often used as a gate to cigarette and marijuana smoking [11] or are even a vehicle for using soft and heavy drugs such tetrahydrocannabinol (THC), cocaine, heroin or, lastly, fentanyl [21–23].

Results of a number of clinical and epidemiological studies indicate on cardiovascular effects of e-cigarette use. Nicotine may contribute to increased heart rate, blood pressure, increased blood viscosity and the risk of blood clots as well to multiple vasoconstriction and increased risk of blood vessels rupture [18, 19]. It all substantially increases the risk of stroke, pulmonary embolism and heart attack [1, 11].

Although e-cigarette aerosol contains fewer numbers and lower levels of most toxicants that are observed in the smoke of combustible tobacco products, especially in manufactured cigarettes [13], e-cigarettes generate chemical compounds that have carcinogenic properties and are known to cause cancer, even in small, trace doses [11]. Latest investigation indicates that a condensate of disposable e-cigarette aerosol

may enhance the metabolism of benzo(a)pyrene, a strong carcinogen, to genotoxic products in a human oral keratinocyte cell line [24]. Other studies show that prolonged use of e-cigarettes may contribute to overheating the e-cigarette battery and then to the significant increase in the content of some carcinogenic substances such as formaldehyde and benzene even to the level observed in smoked conventional cigarettes [8, 18, 25]. The overheated e-cigarette battery can also explode contributing to serious accidents, injury and burns [1, 19, 26]. Results of the latest clinical studies suggest that e-cigarette use may contribute to the risk of urinary tract cancers since biomarkers of carcinogenic substances responsible for bladder cancer formation were found in the urine of e-cigarette users [27].

A number of clinical and epidemiological studies indicate on pulmonary effects of e-cigarette use [19]. Propylene glycol and glycerin, humectants that are ingredients of e-liquid and effective solvents for nicotine in aerosol, are well known pulmonary irritants when heated in e-cigarettes [28]. Some e-liquid flavors such as diacetyl have also pulmonary toxic properties and when intensively inhaled may lead to bronchiolitis [28]. Intensive puffing of e-cigarette also expose users to higher amounts of carbonyls that contribute to pulmonary disease in smokers [8]. Heating of tetrahydrocannabinol (THC), a marijuana's psychoactive ingredient, when added to e-cigarette liquid (what occurred on broad scale in the United States and in limited extent in Poland), substantially increases the risk of lung injury (defined by the US Food and Drug Administration as EVALI) or even death [28].

The newest analysis of clinical and epidemiological studies, that makes an attempt to summarize previous results of 107 studies and to analyze 124 population-based pooled odds ratios, shows that the odds ratios for cardiovascular disease, stroke and metabolic dysfunction do not differ among e-cigarette users and cigarette smokers, and current dual use of e-cigarettes and conventional cigarettes is associated with 20 to 40% higher odds of almost all health outcomes than for cigarette smoking [29, 30].

Conclusions

The consumption of e-cigarettes has rapidly increased in the last years, both worldwide and in Poland. It especially concerns disposable, one-time use products, and adolescent and youth population. Substantial proportion of e-cigarette users, both among adults and teenagers, also simultaneously smoke cigarettes. For many adolescents, e-cigarettes are a gate to experimentation or regular use of tobacco products or even drug use. And, therefore, tobacco epidemic is rather perpetuating than ending. Despite initial expectations, partly promoted by tobacco industry, partly based on scientific evidence, substitution of tobacco smoking epidemic with the epidemic of e-cigarettes use does not seem to be currently considered as the scientifically justified and the most effective way for reducing the huge health costs of smoking-attributable

diseases. The number of studies that prove negative health consequences of e-cigarette use is steadily increasing. Many toxic and carcinogenic compounds were found in e-cigarettes and, although their content is at much lower level than in combustible tobacco products, there is no safe dose for exposure to these chemical agents. In specific conditions such as prolonged, interrupted e-cigarette vaping, overheating the e-cigarette battery or vaping of e-cigarettes from unknown source, their use can be as dangerous as smoking of conventional cigarettes. There is more scientific evidence that dual use of e-cigarettes and manufactured cigarettes is more risky than cigarette smoking.

Therefore, there is an urgent need to regulate e-cigarettes as strictly as cigarettes and other tobacco products in terms of tax and price policy, advertising, promotion and sponsorship, protection from exposure in public places and workplace, labelling and other regulations concerning manufacture, presentation and sale. The complete ban on sale of disposable e-cigarettes that is now considered to be soon enforced in Poland and came already into force or will be enforced in 2024 and 2025 in other countries, including Australia, Belgium, France, Germany, the Netherlands and the United Kingdom, is a next step forward in implementation of comprehensive tobacco control strategy.

Article information and declarations

Author contributions

Krzysztof Przewoźniak – conceptualization, writing – original draft preparation.

Paweł Koczkodaj – conceptualization, writing – review and editing.

Conflict of interest

None declared

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