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The effect of rising e-cigarette usage among young people on public health and physical activity

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Abstract

Introduction: Electronic cigarettes (e-cigarettes/ENDS) are regarded by many as a safe alternative to traditional cigarettes. This article will present a review of the current knowledge regarding the effects and impact of electronic cigarettes on health and the risk of addiction in adolescents.

Methods: We selected articles with an unlimited search period in several databases, including PubMed, Google Scholar, Web of Science and the websites of the Polish government. Only articles with free full text were included in the review. There were no restrictions based on article type.

Conclusions: The increasing consumption of e-cigarettes (ENDS) among young people in Poland is emerging as a significant public health concern. The high addictive potential of nicotine, coupled with the toxicity of aerosols and the multitude of ways in which manufacturers make their products more appealing, gives rise to the risk of an increase in future patients with impaired performance in sports, and consequently with cardiovascular and respiratory diseases, as well as the necessity to combat addiction. Reducing and preventing the use of tobacco products by children and adolescents represents one of the most significant challenges currently facing the public health sector in Poland.

Keywords: e-cigarette; vaping; ENDS; addiction; youth; adolescents;

1. Introduction

Tobacco smoke exposure represents a significant preventable risk factor for a range of global diseases.¹ According to statistics from the World Health Organization (WHO), more than eight million individuals worldwide die annually from diseases associated with tobacco use.²

In 2003, a Chinese pharmacist developed electronic cigarettes (e-cigarettes) as a potential aid for smoking cessation. The device utilizes battery-powered heating elements to vaporize an e-liquid, which is a solution of glycerol (VG) and/or propylene glycol (PG), creating a smoke-like aerosol. The e-liquid typically contains propylene glycol, glycerol, various flavors, and often nicotine. These products are frequently promoted as a healthier alternative to smoking tobacco.³ Additionally, the levels of toxic substances other than nicotine appear to be considerably lower than those of traditional cigarettes.^{4,5}

In recent years, there has been a notable decline in the consumption of traditional cigarettes worldwide.¹ This decline can be attributed primarily to the implementation of

intensive health promotion campaigns. In contrast, use of electronic nicotine inhalers (hereafter referred to as ENDS), including disposable e-cigarettes (hereafter referred to as disposable ENDS), is increasing significantly.⁶⁻⁸ Surgeon General of the United States Public Health Service, VADM Jerome Adams characterized the use of e-cigarettes by young people as an epidemic.⁹

The proportion of young people aged 15-19 in Poland who exclusively use e-cigarettes increased from 2.0% in 2010/2011 to 11% in 2015/2016.¹⁰ Furthermore, the proportion of female high school students who used e-cigarettes increased from 20.7% (2014/2015) to 31.7% in 2017/2018.¹¹ A survey conducted in Poland as part of the Global Youth Tobacco Survey among young people aged 11-17 in 2016, found that 31.5% of boys and 21.8% of girls were current e-cigarette users.¹² As indicated by data divulged by the Polish Ministry of Health, a study conducted by the Lung Cancer Association based on surveys conducted in December 2023 revealed that nearly half (47.6 percent) of students between the ages of 13 and 19 utilize e-cigarettes on a daily basis, while one in five (21.3 percent) employ flavored, disposable cigarettes. Furthermore, nearly one-third (30%) of students who utilize disposable e-cigarettes do so to the extent that they consume the entire contents in a period of 24 hours or less.^{13,14} A study conducted in 2020 in a comparable population of Polish adolescents documented a 23% prevalence of electronic nicotine delivery system (ENDS) use, with daily ENDS users representing approximately half of this cohort.¹⁵ Moreover, the aforementioned study notes that the age of nicotine initiation is most often between 12 and 14 years. The reduced belief in the addictive potential of e-cigarettes compared to traditional cigarettes (75% vs. 93%) also seems significant.

A synthesis of the findings from these surveys suggests that the prevalence of e-cigarette use among Polish adolescents is on the rise.

2. Nicotine salt vs. free nicotine; menthol and flavorings - impact on the attractiveness of the inhaled liquid

The free nicotine present in tobacco products has a bitter taste and can cause irritation to the respiratory tract.¹⁶⁻²⁰ Lactic acid, benzoic acid, and levulinic acid are the most commonly identified compounds in liquids containing a nicotine salt, where they facilitate the conversion of nicotine from a free base to a protonated salt.²¹ The utilization of ENDS with nicotine salt liquids in comparison to free nicotine preparations has been demonstrated to enhance the sensory experience and mitigate vaping-related side effects, particularly among individuals

who have never engaged in smoking.¹⁶ This enables the inhalation of liquids with a higher concentration of nicotine. Clinical studies have demonstrated that nicotine lactate is absorbed at a greater rate than the alkaline form.²² Given that it reaches high blood concentrations more rapidly, this may have an impact on the greater addictive potential of nicotine salt preparations.

The results of studies conducted on animals and humans indicate that menthol, a common ingredient in liquids, can facilitate smoke inhalation and promote nicotine addiction and smoking-related diseases. This is due to its ability to suppress respiratory irritation.^{18,23–25} It would appear that other non-menthol "ice flavors," such as WS-3 and WS-23 (Wilkinson Sword), are even more appealing for inhalation than natural menthol.²⁶

At the present time, consumers appear to favor fruit flavors,^{27–29} and the wide variety of flavors available for e-cigarettes is one of the primary reasons that younger individuals cite for using vaping products.^{29–33}

It can be postulated that the disparate flavors of e-cigarettes that enhance product tolerance may be a contributing factor to the abuse of these products by adolescents.

3. Toxicity of ENDS

The meta-analysis revealed a significantly elevated risk of asthma and chronic obstructive pulmonary disease (COPD) among users of electronic nicotine delivery systems (ENDS).³⁴ Moreover, several studies have indicated that electronic cigarette users are at a considerably elevated risk of developing COPD when compared to traditional cigarette smokers.³⁵

In vitro studies have demonstrated that exposure to e-cigarette aerosol results in reduced viability of bronchial epithelial cells and increased levels of oxidative stress. Notably, the nicotine concentration had no effect on cell viability.³⁶ ENDS aerosol has been demonstrated to induce reactive oxygen species, which can cause DNA damage and reduce cell viability.³⁷ The daily inhalation of electronic nicotine delivery systems (ENDS) was observed to increase the levels of pro-inflammatory and profibrotic proteins in mice, while simultaneously reducing renal filtration and increasing liver, heart, and kidney fibrosis.³⁸ A study conducted in 2019 in the United States evaluated the toxicity of 20 of the most popular e-liquid flavors. The findings indicated that some of the observed cytotoxic effects may be attributed to

flavorings present in these liquids.³⁹ Other studies appear to corroborate the deleterious effects of aromatics on oxidative stress and lung parenchymal damage.⁴⁰⁻⁴² Furthermore, additional compounds with the potential to cause harm, including coumarin, ethylene glycol, acetamide, and aldehydes, were identified in the fluids.⁴³ Despite the deleterious effects of aromatics, recent studies have demonstrated that unflavored glycerin and propylene glycol, when administered independently, have the capacity to induce an elevation in pro-inflammatory cytokines *in vitro*,⁴⁴⁻⁴⁶ as well as an increase in respiratory mucus.^{45,47} The observed phenomenon may be influenced by the products of PG decomposition under heating, the reaction rate of which is significantly enhanced by the catalytic effect of the metal heater wire. The resulting products include propionaldehyde, acetone, formaldehyde, and acetaldehyde.⁴⁸ Additionally, these two primary liquid components (VG and PG) have been demonstrated to impede glucose uptake into the airway epithelium.⁴⁹

It is also noteworthy that following exposure to ENDS vapor, immune cells present in the respiratory epithelium demonstrated a reduction in antimicrobial activity against *S.aureus*. Additionally, the bacterium exhibited enhanced biofilm formation and invasion of epithelial cells.⁵⁰ Chronic exposure to ENDS vapor has been observed to alter phospholipid homeostasis and impair immune mechanisms within the respiratory system.⁵¹

The acute use of nicotine e-cigarettes was associated with an increase in heart rate, systolic blood pressure, diastolic blood pressure, and augmentation index (AIx75), along with a decrease in fractional exhaled nitric oxide (FeNO). However, exposure to e-cigarettes was not associated with significant changes in any spirometric measurement.⁵²

The regular use of e-cigarettes has been linked to the development of inflammatory processes within the nervous system, which may subsequently give rise to alterations in behavior and the emergence of mood disorders.⁵³

Recent scientific studies have further highlighted the existence of a significant health concern associated with the use of ENDS, namely "e-cigarette, or vaping, product use-associated lung injury," also known as EVALI.^{54,55} The majority of cases associated with this disease have been linked to the consumption of liquids containing THC (tetrahydrocannabinol).^{55,56} ENDS provide the ability to vaporize cannabinoids.⁵⁷ The disease is typified by a constellation of symptoms, including dyspnea, fever, cough, vomiting, diarrhea, headache, dizziness, and chest pain, which manifest after the use of vaping devices.⁵⁸ A significant proportion of patients require hospitalisation, with a subset requiring connection to a ventilator in the intensive care unit (ICU).⁵⁸ Some sources indicate that more

than half of the patients with this condition required an intensive care unit (ICU) stay.⁵⁹ The primary causative agent of EVALI has been identified as vitamin E acetate.⁶⁰

4. ENDS vs sport activity

A study of adolescents revealed a correlation between e-cigarette usage and a reduction in physical activity compared to non-smokers.⁶¹ A further study of a cohort of young men revealed that those who used e-cigarettes had significantly inferior athletic performance compared to non-smokers. Specifically, they completed the 2-mile run 27 seconds slower, performed 4.56 fewer push-ups and 2.01 fewer sit-ups than non-smokers. Furthermore, dual users (i.e., individuals who use both e-cigarettes and traditional cigarettes) exhibited an even more pronounced decline in performance, with a 32-second increase in the completion time of a 2-mile run, 5.17 fewer push-ups, and 3.88 fewer sit-ups compared to non-smokers.⁶²

5. Other correlations

The Fagerström test revealed that nicotine addiction levels were more than twice as high among e-cigarette users (average 3.5) compared to traditional tobacco smokers (average 1.6).⁶³ This finding suggests that e-cigarettes may have a higher addictive potential than traditional cigarettes.

Furthermore, the study revealed that adolescents and adults who utilized electronic nicotine delivery systems (ENDS) exhibited an elevated likelihood of subsequently initiating the use of traditional tobacco products when compared to those who had never employed ENDS.⁶⁴⁻⁷¹ A positive correlation exists between the frequency of social media use and the increased likelihood of ENDS use.⁷² The use of ENDS during adolescence is associated with an increased likelihood of subsequent use of cannabis, alcohol, and attention deficit hyperactivity disorder (ADHD) treatment drugs, including methylphenidate (Ritalin) and dextroamphetamine (Adderall), compared to those who have never used ENDS.^{73,74} Furthermore, exposure to electronic cigarette advertisements has been demonstrated to diminish children's perceptions of the harm associated with occasional smoking.⁷⁵

6. Conclusions

The use of a protonated form of nicotine in a multitude of flavors by manufacturers has increased the appeal of these products, which may contribute to their addictive potential. Furthermore, the initiation of vaping at a young age is associated with an increased risk of consuming traditional cigarettes, the toxicity of which has been well-documented for many years. The impact of ENDS on impaired physical performance appears to be a significant concern. The growing number of scientific studies confirming that ENDS have a notable impact on health should prompt further scientific research on the subject and contribute to discussions about potential legislative changes to prevent more young people from developing this habit.

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