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FEATURES OF THE RESPIRATORY AND CARDIOVASCULAR SYSTEM IN YOUNG INDIVIDUALS USING ELECTRONIC NICOTINE DELIVERY SYSTEMS

Abstract. Tobacco smoking is one of the five leading risk factors for non-communicable diseases. The focus of the medical community on this factor is driven by its modifiability and the global burden of cardiovascular and respiratory pathologies associated with tobacco use. Despite initial perceptions of electronic cigarettes as smoking cessation aids and harm reduction tools, aggressive marketing campaigns have led to their widespread popularity over the past 15 years. Evidence regarding the impact of electronic cigarettes on human health is still lacking. Objective: To analyze the effects of electronic cigarettes on the respiratory and cardiovascular systems of young smokers in comparison to individuals who have never used electronic or conventional cigarettes. Materials and Methods: A total of 102 individuals aged 20 to 35 years, who were considered somatically healthy at the time of health assessment, were examined. The main group consisted of 66 individuals who had been using electronic nicotine delivery systems for a period ranging from 1 month to 3.5 years (M(SD)), and the control group comprised 36 individuals who had never smoked electronic or conventional cigarettes. Spirometry and calculation of indices of respiratory and cardiovascular system function were used as the methods of assessment. Results: The spirometry data indicated an increased risk and tendencies toward the development of initial signs of obstruction in the group of electronic nicotine delivery system users. Further analysis revealed a statistically significant difference between the comparison groups, suggesting a decrease in cardiovascular reserve and a reduction in the organism's metabolic and energy potential among electronic cigarette users. Conclusions: Individuals using electronic tobacco heating systems exhibited lower basic indicators of lung functional capacity compared to the non-smoking control group. The state of

cardiovascular system reserves, as assessed by the Robinson index, was "below average" for electronic cigarette users, while the control group exhibited an "average" potential ($p=0.0433$). Unlike the healthy control group of adolescents with predominantly sympathetic autonomic nervous system regulation, young users of electronic nicotine delivery systems predominantly displayed a parasympathetic type of autonomic regulation.

Keywords: heated tobacco products, smoking, external breathing function, respiratory pathology, autonomic dysfunction.

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ОСОБЛИВОСТІ СТАНУ ДИХАЛЬНОЇ ТА СЕРЦЕВО-СУДИННОЇ СИСТЕМИ У МОЛОДИХ ОСІБ, ЩО КОРИСТУЮТЬСЯ ЕЛЕКТРОННИМИ СИСТЕМАМИ ДОСТАВКИ НІКОТИНУ

Анотація. Тютюнопаління є одним з п'яти провідних факторів ризику розвитку неінфекційних захворювань. Концентрація зусиль медичної спільноти на цьому факторі спричинена можливістю його модифікації, а також через зумовлений вживанням тютюну глобальний тягар серцево-судинних та респіраторних патологій. Незважаючи на початкове уявлення щодо електронних сигарет, як засобу відмови та пом'якшення наслідків тютюнопаління, агресивна маркетингова кампанія призвела до їх популяризації протягом останніх 15 років. Людству досі бракує доказів щодо впливу електронних сигарет на організм. Мета: провести аналіз впливу електронних сигарет на стан респіраторної та серцево-судинної системи у молодих курців у порівнянні з особами, які ніколи не курили. Матеріали і методи. Нами було обстежено 102 особи віком від 20 до 35 років, які на момент оцінки стану їх здоров'я вважались соматично здоровими. Основну групу склали - 66 осіб, які використовували ТВЕН-и протягом від 1 місяця до 3,5 років $M(SD)$; група контролю - 36 осіб, які ніколи курили електронні або промислові сигарети. В якості методів використано спірометрію, підрахунок індексів функціонування респіраторної та серцево-судинної системи. Результати. Отримані дані оцінки показників спірометрії є підґрунтям і вказують на ризики та тенденції до формування початкових проявів обструкції

у групі користувачів електронних систем доставки нікотину. Подальший аналіз показав статистично значущу різницю між групами порівняння, що вказує на зниження резервних можливостей ССС та зниженням обмінно-енергетичного потенціалу організму курців електронних сигарет. Висновки. Представники групи користувачів електронних систем нагрівання тютюну мали статично нижчі основні показники функціональних можливостей легень, порівняно з групою контролю, що не є курцями. Стан резервів серцево-судинної системи, визначений за індексом Робінсона, у групі користувачів електронних сигарет відповідав рівню “нижче середнього”, тоді як для групи контролю був характерний “середній” потенціал ($p=0,0433$). На відміну від групи контролю здорових однолітків, молоді користувачі електронних систем доставки нікотину мали переважно парасимпатичний тип вегетативної регуляції.

Ключові слова: системи нагрівання тютюну, куріння, функція зовнішнього дихання, респіраторна патологія, вегетативна дисфункція.

Introduction. The use of tobacco products has accompanied humanity for more than 2000 years. Non-communicable diseases (NCDs) currently hold a leading position among health issues in the European region. Numerous studies have established the adverse effects of tobacco consumption on various organ systems, which is why tobacco smoking is among the top five risk factors for NCDs [1].

Smoking remains a major global health issue today. Research conducted within the Global Burden of Disease consortium, which examines health problems leading to death and disability, across 204 countries from 1990 to 2019, showed a decrease in the number of smokers worldwide by 33.6%, with approximately 1.14 billion people smoking in 2019 [2].

Nevertheless, the tobacco industry continues to expand its presence in the global market segment through the development of new tobacco consumption devices, widely known as electronic cigarettes or electronic nicotine delivery systems. These are marketed as a safer alternative to traditional tobacco smoking [3]. As a result, the number of e-cigarette users, commonly referred to as "vapers," is rapidly increasing [4]. In 2013, there were 2.8 million vapers globally, which rose to 5.1 million in 2015. In Ukraine, as of 2017, 18.4% of adolescents reported using electronic cigarettes, with boys at 22.6% and girls at 14.0%, which is twice the percentage of daily smokers of traditional cigarettes, accounting for 9.2% of those surveyed (10.8% among boys and 7.7% among girls) [5].

In today's context, the use of electronic smoking devices poses a new challenge for researchers and clinicians due to the limited body of literature regarding the safety of using electronic cigarettes for public health [6].

Researchers pay particular attention to the impact of alternative forms of smoking on cardiovascular and respiratory systems. Given the well-established data on the adverse effects of tobacco smoke in traditional cigarettes, one can hypothesize

that the respiratory system, which first encounters the smoke produced by the tobacco heating system, may potentially sustain various damage [7, 8]. This risk could lead to the development of chronic respiratory conditions, and the detection of these pathological changes in their early stages might manifest as alterations in external respiration function or a reduction in functional capacities among electronic cigarette users.

The potential negative influence of tobacco smoke from tobacco heated products (THPs) on cardiovascular health is also a possibility. Understanding that pathological changes in this system may have a delayed nature, we have hypothesized the possibility of the formation of unstable symptoms or alterations in the functional capabilities and functional reserve of the cardiovascular system in THP users.

Objective: To examine the working hypothesis regarding the possible negative impact of alternative smoking methods on the health of young individuals, conduct an analysis of spirometry data, assess the functional capabilities of the respiratory system using the vital capacity index, and evaluate the functional capabilities and functional reserve of the cardiovascular system (Robinson index; Kerdo index) in young users of tobacco heating systems (THPs) compared to individuals who have never smoked.

Materials and Methods: A total of 102 individuals aged 20 to 35, who were considered somatically healthy at the time of health assessment, were examined. The main group consisted of 66 individuals who had used THPs (electronic cigarettes) for a duration ranging from 1 month to 3.5 years (M(SD)); the control group comprised 36 individuals who had never smoked electronic or traditional cigarettes. Exclusion criteria included the presence of acute or chronic diseases, including exacerbations of chronic inflammatory conditions of the upper respiratory tract, smoking of traditional ("conventional") cigarettes, and individuals younger than 18 or older than 35 years.

Spirometry was conducted to determine standard indicators of respiratory function.

To assess the functional capabilities of the respiratory system, we used the vital capacity index, calculated as follows: Vital Capacity Index (ml/kg) = Vital Lung Capacity (VLC) / body mass index, where VLC is the vital lung capacity in milliliters, and body mass index is in kilograms.

To evaluate the functional capabilities and functional reserve of the cardiovascular system, we utilized the Robinson index and the Kerdo index.

The Robinson index (RI) was chosen as an indicator allowing the assessment of the functional state of the cardiovascular system at relative rest and providing a quantitative evaluation of energy exchange processes within the body. This index can also indirectly investigate the systolic work of the heart. The Robinson index was calculated using the standard formula: $RI = (HR \times SBP) / 100$, where HR represents heart rate (beats per minute), and SBP is systolic blood pressure.

Additionally, we employed the Kerdo index, or the vegetative index (VI), as an indicator used to assess the activity of the autonomic nervous system (ANS) and the balance between its sympathetic and parasympathetic divisions. It is known that the negative effects of tobacco smoke manifest as a disruption in the regulation of bronchial patency by the ANS [10], so the study of its functional status may be associated with the influence of electronic cigarettes. Furthermore, according to other researchers, there is a close relationship between some integral indicators characterizing the state of vegetative-vascular regulation and indicators of respiratory function [11]. The Kerdo index was calculated using the formula: $VI = 100 \times (1 - DAT/HR)$, where DAT represents diastolic blood pressure in millimeters of mercury (mm Hg), and HR is heart rate (beats per minute).

The statistical analysis of the obtained data was conducted using licensed software, specifically Microsoft Excel and Statistica v.6.1. Since more than 90% of the data exhibited a normal distribution, preference was given to parametric statistical methods. The obtained results were considered statistically significant at a significance level (p) of less than 0.05.

Results and Discussion: The statistical analysis of the results (Table 1) revealed that the mean forced vital capacity in percent of predicted (FCV/pred %) in the main group was 88.5217%, while in the control group, it was 90.625%. There was no statistically significant difference found using the T-test ($p > 0.05$), and both groups' lung capacity measurements were within the normal range.

Table 1

Comparison data of spirometry indicators in the main group and the control group

| Parameter | Main Group | | Control Group | | P-Value |
|-------------------|------------|---------|---------------|---------|---------|
| | M | SD | M | SD | |
| FCV | 4.2508 | 0.9349 | 3.7731 | 0.7028 | 0.016* |
| FCV/pred % | 88.5217 | 13.3994 | 90.625 | 8.0232 | 0.429 |
| FEF 25/75 | 4.5922 | 1.7628 | 4.9862 | 1.418 | 0.297 |
| FEF 25/75 /pred % | 96.4783 | 33.5604 | 109.375 | 14.3229 | 0.044* |
| FEF25 | 6.5413 | 2.3208 | 6.8688 | 1.8830 | 0.510 |
| FEF75 | 2.7226 | 1.1902 | 2.9175 | 0.5888 | 0.395 |
| FEV1 | 3.4679 | 1.2387 | 3.5612 | 0.5805 | 0.692 |
| FEV1/pred % | 83.8696 | 26.0603 | 99.1875 | 8.3335 | 0.002* |
| FEV1/FCV | 82.1683 | 23.7225 | 94.7862 | 3.6939 | 0.003* |
| FEV1%/pred % | 103.0909 | 21.6567 | 112.9375 | 4.0556 | 0.013* |
| PEF | 7.8526 | 2.5525 | 7.9456 | 2.3220 | 0.870 |
| PEF/pred % | 87.7826 | 25.5238 | 98.9375 | 16.5216 | 0.032* |

* statistically significant difference at $p < 0.05$ level

A potentially sensitive marker of reduced air flow, FEF 25/75 /pred % [12], according to our study, on average did not exhibit pathological levels in both groups.

In the smokers' group, it was 96.4783%, while in the control group, it was 109.375%. However, this marker of reduced air flow had a statistically lower level in the main group compared to the control group ($p = 0.0443$).

Regarding the Forced Expiratory Volume in 1 second (FEV1/Pred %), which is a primary parameter indicating the presence of bronchoconstriction, the main group had an average result of 83.8696%, while the control group had an average result of 99.187% ($p = 0.002$). The calculation of the average Tiffeneau index (FEV1/FCV) in the main group was 82.1683%, whereas in the control group, it was 94.7862%, with a statistical difference at the level of $p = 0.0039$.

The data obtained from the spirometry parameters assessment provide a basis and indicate the risks and tendencies for the development of initial signs of obstruction in the group of users of electronic nicotine delivery systems. Our findings align with existing literature, which shows that the nicotine-containing aerosol from electronic cigarettes has an acute impact on vascular and pulmonary function, as nicotine in electronic cigarette aerosol has been found to acutely increase flow resistance measured by impulse oscillometry, indicating airway obstruction [13].

The comparison of the functional respiratory, cardiovascular, and autonomic nervous system regulation parameters in patients from the main group and the control group is presented in Table 2.

Table 2

Indicators of functional capabilities of the cardiovascular system in patients of the main and control groups

| Parameter | Main Group | | Control Group | | P-Value |
|----------------|------------|---------|---------------|---------|---------|
| | M | SD | M | SD | |
| Life index | 5.068 | 15.1487 | 58.7648 | 13.4725 | 0.0450* |
| Kerdo index | -6.4952 | 18.2447 | 3.1437 | 12.5586 | 0.0091* |
| Robinson index | 90.9464 | 15.1505 | 84.252 | 13.2958 | 0.0433* |

* statistically significant difference at $p < 0.05$ level

Functional respiratory parameters, as assessed by the vital index, were statistically lower in the group of electronic nicotine delivery system (ENDS) users compared to the control group ($p = 0.045$), indicating a negative impact of electronic tobacco heating devices on the functional respiratory capabilities.

The state of cardiovascular reserves, assessed using the Robinson index, which characterizes systolic heart function, in the main group averaged $M(SD) = 90.9464 (15.1505)$, indicating below-average values. In the control group, this index averaged $M(SD) = 84.252 (13.2958)$, corresponding to an average value. A comparison of the Robinson index revealed a statistically significant difference between the comparison groups, indicating a reduction in cardiovascular reserves and a decrease in the body's metabolic and energetic potential ($p = 0.0433$) in ENDS users.

In the assessment of the Kerdo index (Table 2), it was determined that users of electronic nicotine delivery systems predominantly exhibited parasympathetic regulation of the autonomic nervous system, averaging $M(SD) = -6.4952 (18.2447)$, while in the control group, sympathetic regulation was predominant, averaging $M(SD) = 3.1437 (12.5586)$.

In summary, our hypothesis regarding the adverse health effects on young individuals who use ENDS has been supported by changes in spirometry parameters, indicating the presence of initial signs of bronchoconstriction, reduced functional respiratory capabilities as indicated by the vital index, and a decrease in cardiovascular reserves and metabolic potential (Robinson index). Additionally, there is a prevalence of parasympathetic autonomic nervous system regulation (Kerdo index) in young ENDS users compared to individuals who have never smoked.

Conclusions:

1. Individuals who use electronic tobacco heating systems exhibited statistically lower key lung function parameters compared to the non-smoking control group.

2. The cardiovascular reserves, as determined by the Robinson index, in the group of electronic cigarette users corresponded to a "below-average" level, while the control group demonstrated an "average" potential ($p=0.0433$).

3. Unlike the healthy young individuals in the control group, young users of electronic nicotine delivery systems predominantly exhibited parasympathetic autonomic nervous system regulation.

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