



The global prevalence of E-cigarettes in youth: A comprehensive systematic review and meta-analysis

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ABSTRACT

Objectives: Smoking, especially cigarettes, is known as one of the most common social and health problems among people. E-cigarettes are another form of tobacco that has been an ordinary daily occurrence.

Study Design: systematic review and meta-analysis.

Methods: Systematic searching of databases was performed in Scopus, Web of Science, PubMed, Science Direct, MagIran, IranDoc, SID and Google search engine based on the PRISMA 2020 guideline. This search was conducted by the end of May 2021. Following full-text assessments, the related data were extracted from the papers. Newcastle-Ottawa scale was also used to evaluate the quality of methodology of the articles. Finally, study analysis was performed using Comprehensive Meta-Analysis software (version 2) based on the random effect model.

Results: Global prevalence of E-cigarette in younger individuals was 16.8 (95 % CI: 10.6–25.6) and 4.8 (95 % CI: 3–7.6) in the Ever and Current modes of E-cigarette, respectively. We also found that E-cigarettes were used more common in young boys than young girls in both Ever and Current modes. In young boys, the prevalence of E-cigarette were 18.8 (95 % CI: 8.4–36.8) and 4.9 (95 % CI: 3–8) in both modes of Ever and Current, respectively. In young girls, these factors were 9.9 (95 % CI: 5–18.6) and 1.6 (95 % CI: 1–3.1) in both modes of Ever and Current, respectively.

Conclusions: The global prevalence of e-cigarettes among young people, especially young boys, is increasing. Based on this, the prevention and management of the damage of this social phenomenon requires comprehensive global study, planning and policy.

1. Introduction

According to the World Health Organization (WHO) global reports, more than 1.3 billion people are smoking and approximately 80 % of which were in developing countries. Tobacco consumption is directly associated with increased morbidity and mortality rates and mainly have adverse effects on various parts of the body [1]. The WHO estimates that more than 8 million people die prematurely yearly from tobacco use and, more than 7 million of those deaths result from direct tobacco use [2]. A study showed that about half of premature deaths are related to tobacco abuse, commonly in men aged 30–69 years [2]. On the other hand, tobacco is associated with increased health care costs,

economic losses, and increasing poverty in the world [3]. Developed countries are planning to manage and reduce the rate of tobacco consumption. Despite the limitations of relevant data about the rate of tobacco consumption in developing countries, the statistics represented that tobacco usage is increasing in these regions such as African countries [4].

By 2030, tobacco-related deaths are expected to double in low- and middle-income countries, including African countries [3]. With these conditions, it is expected that African countries will experience a significant growth in tobacco consumption, which can be attributed to urbanization, westernization, and demographic changes, as well as the increasing influence of the tobacco industry [3,4]. Based on one study,

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the overall prevalence of current use of any tobacco product among adolescents was 19.1 %, with more than 23.7 % of males and 13.7 % of females being current users. This study reports that tobacco use and non-user susceptibility to using tobacco products among school-going adolescents in 22 African countries is high [4].

The cigarette is the most common form of Tabacco [3]. 80 % of smokers have experienced smoking before the age of 18 years [1]. E-cigarettes are one of the most popular types of smoking these days. Since E-cigarettes contain nicotine, they are also dangerous for all age groups. Nicotine is a highly addictive material with various side effects on the brain, pregnant women, and fetuses [5]. E-cigarette users were already smokers, or they had experience of addiction cessation in the past [6]. Nicotine and other chemical substances available in E-cigarettes can easily reach the lungs in the form of aerosols. Statistics showed that the rate of E-cigarette consumption is increasing in Britain, the United States, and many European countries [7].

Although it is believed that E-cigarettes are useful in smoking cessation, all health professionals and scientific papers approved the harms of different types of E-cigarettes. They also stated that the E-cigarette is not considered an appropriate option for smoking cessation [8]. While the levels of toxins available in E-cigarettes are lower than other types of ordinary cigarettes, but the nature of chemicals and toxins are different [9].

Despite the different thoughts about the benefits and harms, the use

of E-cigarettes is growing nowadays [6]. According to the report of a study, the proceeds from the sale of E-cigarette increased from 3.2 in 2015 to 7.86 billion in 2019 and are expected to reach more than 9 billion by 2021 [10]. As E-cigarette consumption is ongoing, it is expected to be controlled by management of cigarette marketing, proper implementation of smoke-free laws, and the enactment of E-cigarette laws [9].

Considering that the reports presented by various studies around the world have presented different prevalence's of electronic cigarette consumption in young people and the heterogeneity and dispersion of information causes mistakes in health policymaking in this field because correct policymaking is based on accurate information, therefore, the purpose of this study is to use systematic review and meta-analysis to homogenize information in this field and investigate the global prevalence of e-cigarettes in youth.

2. Methods

2.1. Study Design: systematic review and meta-analysis

This study was conducted based on the criteria of the PRISMA 2020 Statement (Preferred Reporting Items for Systematic Review and Meta-analysis), including; systematic database searching, organization of documents, selection of studies in accordance with the criteria defined

Table 1
General information extracted from studies.

NO.	First author	Year of publication	Year of assessment	Country	mean age	SD	Total numbers of cases	Number of analyzed cases	E-cigarette (Ever)	E-Cigarette (Current)
1	Takuma Ofuchi [11]	2020	2019	Thailand	15.3	–	6167	6167	–	1295
2	Mateusz Jankowski [12]	2020	2017–18	Poland	21.9	±2.1	7324	7324	–	95
3	Anastasios Fotiou [13]	2015	2014	Greece	15	–	1320	1320	219	–
4	Li-Chuan Chang [14]	2020	2018	Taiwan	15.13	–	1501527	1501527	–	40470
5	Soteris Soteriades [15]	2020	2013	Greece	14	–	5127	4618	568	129
6	Teresa W. Wang [16]	2019	2019–18	United States	13.5	–	27000000	26900000	9430000	–
7	Oladimeji Akinboro [17]	2019	2014–17	United States	60.32	–	3162	3162	–	116
8	Kate Babineau [18]	2015	2014	Ireland	16.5	–	821	821	196	–
9	Grzegorz Marek Brozek [19]	2019	2017–18	Central and Eastern Europe	20.9	±2.4	14352	14344	6272	–
10	Maria Cooper [20]	2015	2014	Texas	14.49	±1.98	13602	13602	–	1402
11	Martin Eichler [21]	2016	2016	Germany	47.78	–	4002	4002	473	56
12	David Hammond [22]	2019	2017 2018 2017 2018 2017 2018	Canada – England – US –	17.6 17.5 17.5 17.6 17.5 17.5	±1.05 ±1.08 ±1.02 ±1.05 ±1.08 ±1.07	23928 – – – – –	4038 2835 3995 3902 4095 4045	1182 1425 1348 1276 1283 1360	340 562 347 346 454 655
13	Nan Jiang [23]	2016	2012–13	Hong Kong	14.8	±1.9	45857	45857	–	560
14	Heewon Kang [24]	2020	2018	Korea	15	–	59532	59532	4248	1371
15	Biljana Kilibarda [25]	2019	2017	Cerbia	14	–	3360	3256	–	206
16	Sungkyu Lee [26]	2014	2011	Korea	15.5	–	75645	72285	1059	832
17	Daniel Owusu [27]	2017	2016	Central Appalachia	16	±1.4	894	894	314	96
18	Luhua Zhao [28]	2019	2014	China	41.62	–	31151	31151	903	249
19	Christina Jeon [29]	2016	2015	Korean	17	–	4911	4911	34	65
20	Andrea K. Bowe [30]	2021	2018	Ireland	15.5	–	4490	4422	–	225
21	Karen A. Cullen [31]	2019	2019	United States	14.5	±2.9	19018	18938	–	3611

by the authors, data extraction, data analysis, and presentation of the final report.

2.2. Searching strategy

The systematic search was applied in four international databases, including PubMed, Scopus, Web of Science, and Science Direct and three Iranian databases, including SID, MagIran, and IranDoc. Besides, the Google Scholar search engine was also used. English and Persian keywords were hired for international and Iranian databases, respectively (Table 1). They were selected based on the previously published articles and MESH Terms using PICO criteria and research questions. PICO criteria were; Participation (young people from all over the world), Exposure (young E-cigarettes smokers), Comparison (different communities in terms of E-cigarette), Outcomes (global prevalence of E-cigarettes among youth). The Boolean search method was used to combine the keywords. Also, the references of previous studies were used to find the experimental studies related to the research strategy. This search was conducted by the end of May 2021.

2.3. Inclusion and exclusion criteria

In the present study, the inclusion criteria were cross-sectional studies examining the prevalence of smoking, the studies with available data of sample volume and the number of E-cigarette smokers, and the studies with full-text availability. Exclusion criteria were observational studies such as cohort and case-control, case series studies, case report investigations, intervention studies, clinical trials, and review articles.

2.4. Study selection

Following searching and collection of the scientific papers, the assessment and study selection were applied using Endnote software. Two researchers (ND and SR) assessed the studies blindly and independently according to the criteria and the title/abstract of papers. In case of disagreement between these two authors, the third author (MM) assessed the study for the final decision. Following primary confirmation of the studies (ND and SR), they were evaluated according to PICO criteria.

2.5. Quality assessment of study

Newcastle-Ottawa scale (NOS) was used to evaluate the methodological quality of the articles [32]. According to this guideline, three items were examined and scored in each study, including; participants, comparability, and outcomes. The articles with score >7 were considered high (9 was the maximum score), 4–6 were grouped as medium, and the papers with the score of 0–3 were low-quality papers.

2.6. Data extraction and analysis

Using pre-designed forms, the data were extracted, including the first author's name, year of publication, country, sample size, and mean age. Comprehensive Meta-Analysis software (version 2) was used to analyze the data. Due to the high number of studies in this systematic review, the Begg and Mazumdar test at a significance level of 0.1 and the related Funnel plot (to investigate the Publication bias) were hired. I^2 test was also used to evaluate the heterogeneity of studies. Finally, by using the meta-regression test, the relationship among the prevalence of E-cigarettes in the youth with the sample size, year of publication, and age of participants was investigated. Also, the meta-analysis was applied by continent and gender.

3. Results

Based on the three-step process of PRISMA2020, including the identification of screening articles and finally the articles entered into the meta-analysis, and based on Fig. 1, articles in the Scopus, Web of Science, PubMed, Science Direct, MagIran, IranDoc, SID and Google search databases. It was obtained that out of this number, 857 articles were similar and duplicated by reviewing EndNote software. The number of articles that entered the screening stage was 2545, and by removing duplicate articles and articles not related to the study title and studies that did not have enough information to be used in the study, 21 studies were examined (Fig. 1). It is reported in Tables 1 and 2.

3.1. Prevalence of E-cigarettes among the world's youth (Ever mode)

The publication bias was not statistically significant ($P = 0.536$) in this value (Fig. 2). Heterogeneity criteria were also reported as I^2 : 99.8, in which the random analysis method was used due to the high heterogeneity of studies. According to the meta-analysis, the prevalence of E-cigarette in younger individuals was reported 16.8 (95 % CI: 10.6–25.6) in the mode of Ever (Fig. 3).

3.2. Prevalence of E-cigarettes among the world's youth (current mode)

Following analysis of the publication bias using the Begg test, not statistically significant at the level of 0.1 ($P = 0.142$) were reported (Fig. 4). In heterogeneity assessment, the I^2 was found 99.8; thus, the random analysis method was used due to the high heterogeneity in the studies. Also, the total prevalence of E-cigarette (Current mode) was reported 4.8 (95 % CI: 3–7.6) in young people (Fig. 5).

3.3. Subgroups analysis by genders

Based on the results of subgroup analysis, the prevalence of both modes of E-cigarettes, including Ever and Current in young boys were 18.8 (95 % CI: 8.4–36.8) and 4.9 (95 % CI: 3–8), respectively. In young girls, these values were 9.9 (95 % CI: 5–18.6) and 1.6 (95 % CI: 1–3.1) in modes of Ever and Current, respectively (Table 3).

4. Discussion

In the present study, the global prevalence of E-cigarettes was studied among young people. Meta-analysis findings indicated that the total prevalence of E-cigarettes was 16.8 (95 % CI: 10.6–25.6) and 4.8 (95 % CI: 3–7.6) in both modes of Ever and Current, respectively. Also, the global gender-based prevalence of E-cigarettes was 18.8 (95 % CI: 8.4–36.8) and 4.9 (95 % CI: 3–8) respectively in both modes of Ever and Current in young boys. In young girls, these findings were 9.9 (95 % CI: 5–18.6) and 1.6 (95 % CI: 1–3.1) in modes of Ever and Current, respectively. These results indicated that the prevalence of E-cigarette smoking in Ever and Current modes of young boys were respectively 2 and 3-fold higher than young girls.

Based on public belief and unreliable evidence or uncontrolled clinical trials, E-cigarettes are useful in smoking cessation. However, a longitudinal analysis study did not report a significant difference in smoking cessation rates among E-cigarettes smokers and non-smokers [11–13]. These misconceptions led to the increasing desire of young people to smoke E-cigarettes. Other factors involved in increasing the prevalence of E-cigarettes include; restrictions of smoking in public places, home or work, as well as the increasing price of cigarettes [11]. The present meta-analysis study was conducted in two modes of E-cigarette consumption; Ever and Current. Ever mode E-cigarette was defined as at least an experience of smoking [14–25]. In most articles, the Current mode of E-cigarettes smoking was defined as at least an experience of E-cigarettes smoking in the last 30 days [18–21,23,26–31, 33]. In several articles, the Current mode of E-cigarettes was defined as

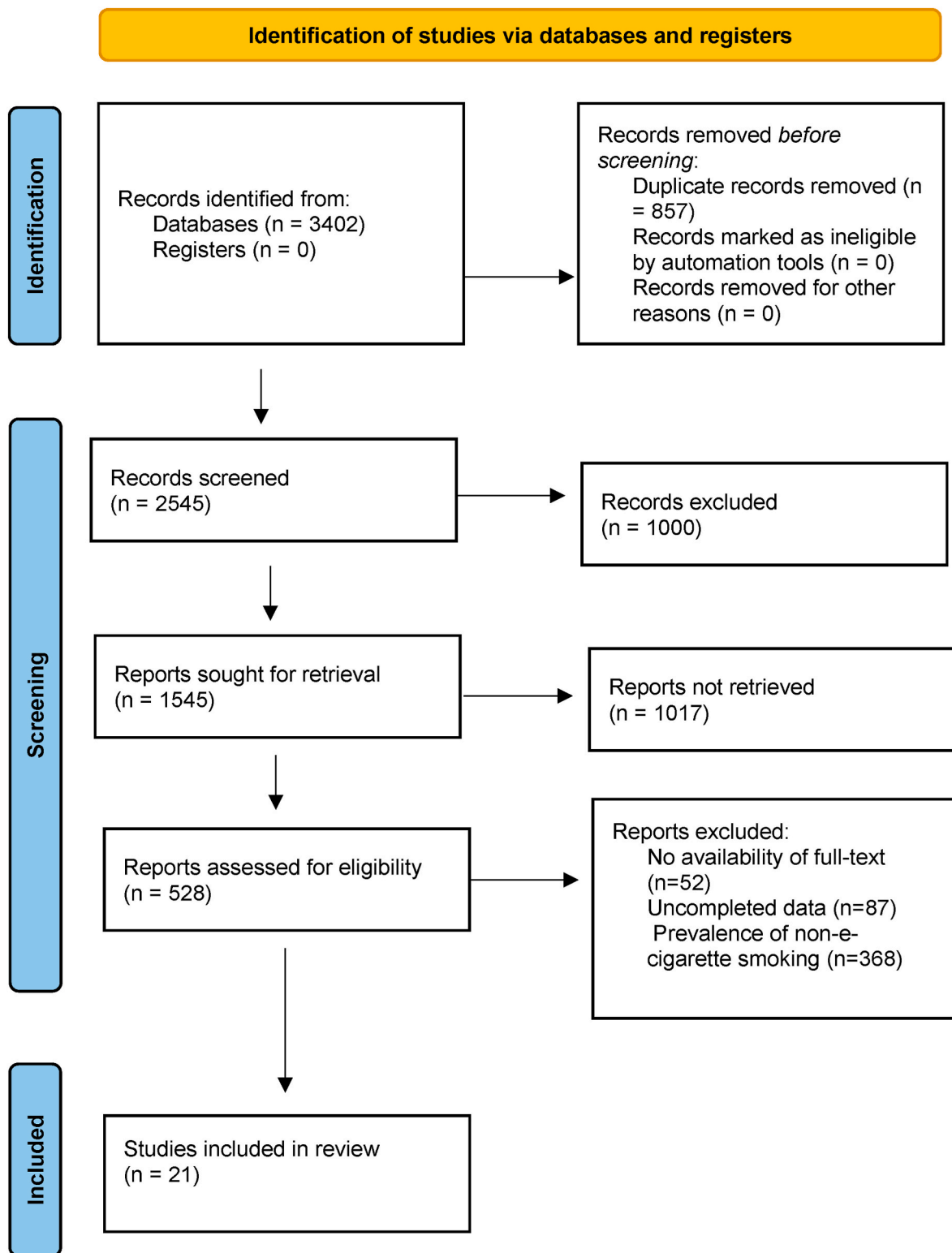


Fig. 1. Articles screening process based on PRISMA 2020.

those who currently smoke E-cigarettes [16,22,25,34,35].

Data on the long-term effects of E-cigarettes is limited and uncertain. Nonetheless, many studies reported that E-cigarette users are exposed to large amounts of toxic chemical compounds, including carbonyl, volatile organic compounds, and nicotine, as harmful for both consumers and adjacent individuals. It has been reported that nicotine-containing E-cigarettes strengthen the person’s physical dependence on nicotine

with adverse effects on brain function of growing adolescents [5,36,37]. However, studies have shown that the toxic chemical compounds of E-cigarettes are less than ordinary cigarettes, but there is much debate about the components and toxicity [38]. According to the series of experiments, E-cigarettes have detrimental toxins and carcinogens [39–41].

Information about E-cigarettes is more limited in adolescents than

Table 2
Information extracted from studies by gender.

NO	First Author	Year of Publication	Date of Data Extraction	Country	Total No of cases	No of analyzed cases	No of young boys	No of young girls	Young Boys		Young Girls	
									E-cigarette (Ever)	E-Cigarette (Current)	E-cigarette (Ever)	E-Cigarette (Current)
1	Takuma Ofuchi [11]	2020	2019	Thailand	6167	6167	2869	3298	247	–	187	–
2	Mateusz Jankowski [12]	2020	2017–18	Poland	7324	7324	2391	4925	1227	–	2063	–
3	Anastasios Fotiou [13]	2015	2014	Greece	1320	1320	638	682	146	51	73	7
4	Soteris Soteriades [15]	2020	2013	Greece	5127	4618	2378	2240	-	93	–	38
5	Grzegorz Marek Brożek [19]	2019	2017–18	Central and Eastern Europe	14352	14344	4252	10092	2181	85	4087	81
6	Maria Cooper [20]	2015	2014	Texas	13602	13602	6790	6812	–	858	–	544
7	Martin Eichler [21]	2016	2016	Germany	4002	4002	1951	2051	293	38	180	18
8	Nan Jiang [23]	2016	2012–13	Hong Kong	45857	45857	24740	21117	–	394	–	166
9	Biljana Kilibarda [25]	2019	2017	Cerbia	3360	3256	1613	1637	–	125	–	81
10	Sungkyu Lee [26]	2014	2011	Korea	75645	72285	35390	36895	–	2776	–	660
11	Daniel Owusu [27]	2017	2016	Central Appalachia	894	894	377	517	164	63	150	33
12	Luhua Zhao [28]	2019	2014	China	31151	31151	15008	16143	750	225	97	17
13	Christina Jeon [29]	2016	2015	Korean	4911	4911	2662	2249	25	55	9	12
14	Andrea K. Bowe [30]	2021	2018	Ireland	4490	4422	2170	2237	1010	412	766	225

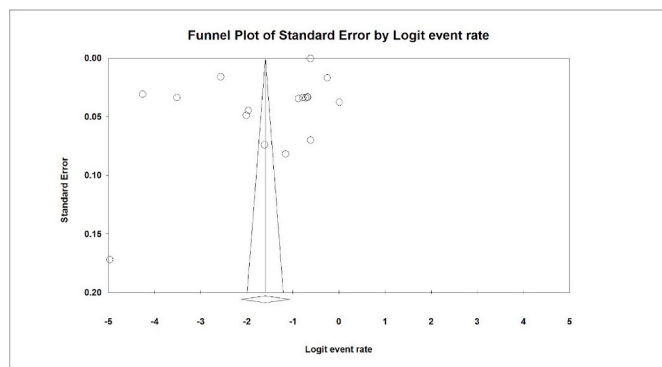


Fig. 2. Funnel plot diagram representing emission bias in E-cigarette (Ever).

adults. According to a study in northeastern Tennessee, an increased prevalence of E-cigarette smoking (Ever) was found in which one in three students (36 %) has experienced at least once E-cigarette smoking [22]. On the other hand, in various studies conducted in the United States, Korea, and many European countries, the results showed that the use of E-cigarettes is increasing rapidly, especially in European countries. In the United States, E-cigarette (Ever) smoking has increased from 3.3 % in 2011 to 6.8 % in 2012, and in Korea, from 0.5 % in 2008 to 9.4 % in 2011 [21,42,43]. Increasing consumption and experiences of E-cigarettes has concerned public health advocates. This incidence confirms the generation of new addicts and the normalization of smoking [44,45].

As mentioned previously, one of the most critical factors of E-cigarettes consumption is curiosity or a tool to cessation or reduce the smoking rate. Unexpectedly, the prevalence of Ever mode is higher than

Meta Analysis

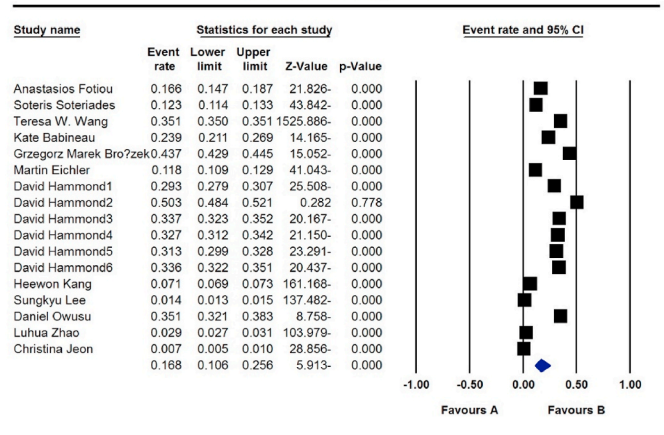


Fig. 3. Forest Plot of the total prevalence of E-cigarette among young people (Ever).

the Current in many people using E-cigarettes for smoking cessation [46]. According to studies conducted in Greece among the students aged 13 to 15, the prevalence of E-cigarette with Current mode was accelerated with increasing the age range (prevalence of 1.1 % in age 13, 3.2 % in age 14, and 4.7 % in age 15) [23]. According to the same study conducted in Greece, other factors affecting the Current mode of E-cigarettes included the consumption of any combustible tobacco products in a Current mode, low level of education of the father, and the

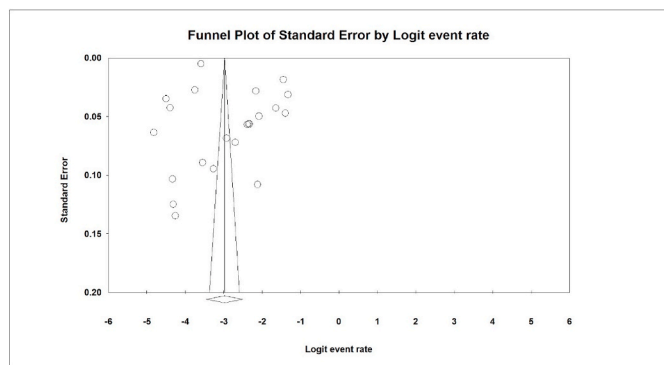


Fig. 4. Funnel plot representing Emission bias in E-cigarette (Current).

Meta Analysis

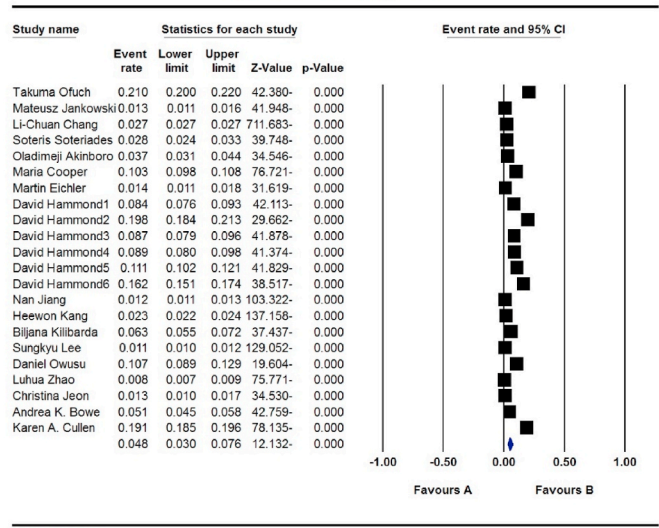


Fig. 5. Forest Plot diagram of the total prevalence of E-cigarette among young people (Current).

Table 3
Results of subgroup analysis by genders.

E-cigarette	N	Sample size	I ²	Begg and Mazumdar test	Prevalence (95 % CI)	
Ever	Young	9	32318	99.8	0.348	18.8 (95%CI: 8.4–36.8)
	Boys	9	36297	99.7	0.118	9.9 (95 %: 5–18.6)
Current	Young	12	94953	99.5	0.631	4.9 (95 % CI: 3–8)
	Boys	12	99750	99.3	0.731	1.6 (95 % CI: 1–3.1)

use of E-cigarettes by other family members [23]. People with daily smoking have the highest chance of E-cigarettes consumption with Current mode; besides they are present in large numbers than individuals with no experience of smoking or smoking cessation [19,21].

In the present study, the consumption of E-cigarettes with both modes of Ever and Current are significantly higher in men than women, which is in line with the results of other studies confirming that the E-cigarettes are significantly different among both genders of males and females [15–17,19,22,25,26].

Also, the use of electronic cigarettes can have many environmental effects, as reported in a review conducted in this field, the impacts on air quality, water, land use, animals, water, and energy consumption, with associated environmental impacts, increased pollution and emissions due to greater e-cigarette production, having harmful and toxic components, creating pollution and waste issues, and global environmental impacts due to manufacturing and importing ingredients and components from low- and middle-income countries, were identified as the environmental impacts of e-cigarettes.

4.1. Limitation

The most significant limitation of this study can be pointed to the regional, climatic and ethnic changes in the prevalence of e-cigarette use, as well as changes in data collection methods in different studies and changes in consumption patterns among young people are among the limitations of this study., and there was also high heterogeneity in this study, which was analyzed by subgroup analysis.

5. Conclusions

According to the present study results, the prevalence of E-cigarettes is increasing among the world’s youth, especially young boys. Thus, prevention and management of the harms of this social phenomenon in the world’s youth require comprehensive study and global planning and policy.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

Datasets are available through the corresponding author upon reasonable request.

Funding

Not applicable.

Plain English summary (PES)

Smoking, especially cigarettes, is considered one of the most common social and health problems. Systematic searching was performed in various databases (Scopus, Web of Science, PubMed, Science Direct, and Google scholar search engine) based on the PRISMA 2020 guideline. Following full-text assessments of the included papers, the associated data were extracted. The Newcastle-Ottawa scale was also used to evaluate the quality of studies, methodologically. Global prevalence of E-cigarette in younger individuals was found 16.8 (95 % CI: 10.6–25.6) and 4.8 (95 % CI: 3–7.6) in the Ever and Current modes, respectively. The global prevalence of E-cigarette is increasing among the youth, especially younger boys.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Abbreviations

WHO	World Health Organization
SID	Scientific Information Database
MESH	Medical Subject Headings
WoS	Web of Science
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
NOS	Newcastle-Ottawa Scale

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