REVIEW ARTICLE

Trend of Electronic Cigarette Use Among Adult Population in Multiple Countries Across Regions: A Systematic Review

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ABSTRACT

Introduction of electronic cigarette (EC) in the global market posed a new challenge to public health experts in terms of controlling the widespread use of the device among general population. This systematic review aimed to explore the trend of EC use among population of adults reported in literature across multiple regions. Using Scopus search engine and several screening strategies, specific keywords were applied in the advanced search field and the search have yielded a total of 33 articles. The key findings include i) the existence of dual users of EC and conventional cigarette smokers and ii) the emergence of EC users who previously never smoked reported among adult populations. The present study suggests that future tobacco control strategies should be strengthen in preventing the initiation of nicotine addiction among non-smoking population and established nicotine replacement therapy instead of EC should be further promoted smokers as a method to quit smoking.

Keywords: Smoking, Smoking cessation, Nicotine addiction, Electronic cigarette

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INTRODUCTION

Electronic cigarette (EC), a battery-powered electronic nicotine delivery device (ENDD) was invented by a Chinese pharmacist named Hon Lik in 2003. In 2004, the device was marketed in China as a smoking cessation tool (1, 2). However, since 2006, introduction of the device into the global market was surrounded by health controversy and has been debated among public health practitioners whether its benefit outweighed the potential health impacts. To address the issue, there have been several different positions issued by international medical and regulatory bodies regarding the use of EC either for smoking cessation or as a gateway to other tobacco products.

In 2016, World Health Organization (WHO) came out with a stand that due to inadequate evidence on the efficacy of EC to promote smoking cessation, WHO has disapproved EC as one of the smoking cessation aid (3). However, despite the stand by WHO and the nonconclusive evidence on the efficacy of EC as a smoking cessation tool (4,5), the device was accepted by a large number of smoker populations. More than 50% (68.1%) of adult EC users were current conventional cigarette smokers (6); who treated EC as a promising smoking quitting tool.

With advancement of product marketing (7), enhanced varieties of e-liquids flavours (8) and the widespread positive perception on product safety compared to conventional cigarette, the popularity of EC has increased among young population and those who never smoked (9). Focusing on these issues reported in multiple countries, this systematic review aimed to explore the trend of EC use among adult population across regions.

MATERIALS AND METHODS

Search strategy

A systematic advanced search of literature was performed to identify eligible articles published in English literature in Scopus database from 2013 till 2019. Considering that EC have been widely marketed worldwide since 2003 (started in China) till 2009, when it started to penetrate the Asian market, this range of publication year (2013-2019) is expected to cover many articles conducted in various countries and regions. The keywords used were multiple combination of terms including “electronic nicotine delivery device”, “electronic cigarette”, “e-cigarette”, “health survey”, “young adults”, “vaping” and “prevalence”.

Selection criteria
Articles were eligible to be included in the study if these specific criteria were satisfied, namely:

1) Article publication stage: Final
2) Article access type: Open access article
3) Type of article: Original article
4) Publication year: 2013-2019
5) Language: English

However, the articles will be excluded from this review if other kind of new-advanced tobacco products were the focus of that particular study.

Study selection
All the relevant articles were identified and assessed by two independent investigators prior to being included in this review. The articles were screened according to the title and abstract. Then, irrelevant articles were excluded, and full-text screening of selected articles were performed.

Data extraction
Specific information was extracted from the included articles such as authors, year of publication, data sources, method of survey dissemination, country, numbers of respondents, study design, and trend of EC use as summarised in Table 1.

RESULTS

The advanced search using specific keywords ["electronic cigarette*" OR "e-cigarette*" OR "electronic nicotine delivery device") AND (prevalence*)] identified 783 articles, but 685 articles were excluded through screening of title and abstract. The full-text of 98 articles were assessed for the trend of EC use among adult population and 33 articles were eligible to be included in this systematic review. Figure 1 presents a flow chart of systematic review steps carried out in this review study.

American Region
A total of 14 included studies have been conducted in the American region in which majority of these surveillance studies involved the US population (10-24).

Based on the data of the Behavioral Risk Factor Surveillance System 2016 involving 50 states and the District of Columbia, a study by Hu and colleagues (2019) (22) has reported higher number of current EC users (22.1%; 95% CI 20.4-23.7) than ever EC users (n = 4.7%, 95% CI 3.9-5.5) among adults in the age of 18 years old and above. Apart of showing similar trend of current and ever EC user prevalence with preceding study, the finding of the US national representative study in 2014 and 2016 have also revealed increment in the number of current EC user prevalence by 3% (2014 = 12.6% & 2016 = 15.3%) while the prevalence

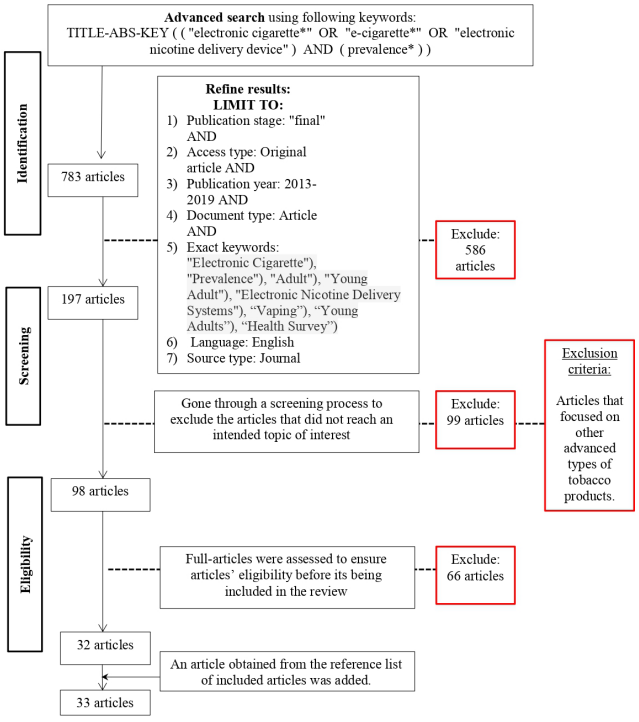

Figure 1 : Flow chart of systematic review on the distribution of EC usage among adults worldwide using Scopus engine search

of current EC users declined by 0.5% (2014 = 3.7% & 2016 = 3.2%) in two consecutive years (21).

Other than providing the prevalence data of EC users, a study conducted among adults in Los Angeles County was also focused on examining the socio-demographic disparities of EC users (24). It has been revealed that male adults who were in the range of 18 to 24 years old were 12 times (95% CI 7.89–18.21) more likely to ever use EC compared to those in the age of 50 years old and above. Furthermore, educational level has also been associated with the higher chances of ever using EC compared with other remaining groups; in which those attained a tertiary educational level was two times (95% CI 1.02-2.26) more likely to try EC than others (adjusted odd ratio 1.46, 95% CI 0.98-2.18).

The increasing number of dual user group among EC users has been frequently issued in other studies (22, 24). The proportion of conventional cigarette smoker (range of prevalence across all states = 36.7% to 70.5%) among current EC users, who also known as dual user was higher than ex-smokers (range of prevalence across all states = 10.5% to 28.2%) (22). A study by Du and colleagues (2019) (24) conducted among 7,919 adults in the Los Angeles County has also demonstrated similar trend. Among a group of current EC users, 28% of them were conventional cigarette smokers (95% CI 23.8-32.1) while only 13.1% (95% CI 10.5-15.8) and 3.5% (95% CI 2.6-4.3) were ex-smokers and never-smoked users, respectively.

Table I : Distribution of prevalence of EC use among adult populations across multiple countries

Authors & Year of publication	Data sources	Method of survey dissemination	Country	No. of sample	Study design	Result	Key finding
American Region							
Regan et al., 2013 (10)	Consumer-based mail-in survey 2009-2010	Mail-based survey	United States (US)	20, 915 adults	Cross-sectional in prospective cohort study	Increase prevalence of ever use: - 2009 (0.6%) - 2010 (2.7%)	Increased prevalence of ever EC user
Mazurek, Syamlal, King & Castellan, 2014 (11)	National Health Interview Survey (NHIS) 2005 & 2010	In-person survey	US	- 2005 (n = 19,445) - 2010 (n = 15,649)	Cross-sectional study	Prevalence of smokeless tobacco users by industry: - Education services = 1.5% - Mining industries = 18.8%	High numbers of smokeless tobacco users in mining industries
Littlefield, Gottlieb, Cohen & Trotter, 2015 (12)	NA	Self-report questionnaire	US	599 college students	Cross sectional	Prevalence of: - Ever used EC = 29%	High numbers of ever EC users
Ramo et al., 2015 (13)	Data obtained from three cross-sectional studies	Online survey	US	- Study 1 (2009–2010) = 1,987 - Study 2 (2010–2011) = 595 - Study 3 (2013) = 79	Cross-sectional	Prevalence of past month use of EC: - Study 1 = 6% - Study 2 = 19% - Study 3 = 41%	Numbers of past -month EC users increased over the years
Delnevo et al., 2016 (14)	National Health Interview Survey 2014	Interview session	US	36,697 respondents	Cross-sectional	Prevalence of EC user: - Current users (daily)= 1.1% - Non-daily users = 2.6% - Ever tried users = 8.9%	High numbers of ever-tried user
Syamlal, Jamal, King & Mazurek, 2016 (15)	National Health Interview Survey (NHIS) data 2014	Interview session	US	36,697 respondents	Cross-sectional	Prevalence of current EC users: - Dual users = 16.2% - Ex-smokers = 4.3% - Never-smoked users = 0.5%	High numbers of dual users
Kenne, Fischbein, Tan, Banks & Mark, 2017 (16)	NA	Online survey	US	1,542 respondents	Cross-sectional	Prevalence of EC user who were: - Never smoked = 45.3% - Dual users = 37.7% - Ex-smokers = 17%	High numbers of never-smoked users and followed by dual users
Syamlal, King & Mazurek, 2017 (17)	National Health Interview Survey (NHIS) data for 2014–2016 to	In-person survey	US	- 2014 = 36,697 - 2015 = 33,672 - 2016 = 33,028	Cross-sectional	Prevalence of EC use among workers in: - Accommodation & food service industry = 5.8% - Installation, maintenance, & repair occupations = 7.9%	High numbers of EC users in Installation, maintenance, & repair sectors
Syamlal, King & Mazurek, 2018 (18)	National Health Interview Survey 2014-2016	Interview session	US	- 2014 = 36 697 - 2015 = 33 672 - 2016 = 33 028	Cross sectional	Prevalence of: - CC* smokers = 24.4% - Cigar users = 8.3% - Smokeless tobacco users = 7.8% - EC users = 4.4% - >2 tobacco products users = 7.6%	High numbers of dual users who were currently smoked CC
Oliveira et al., 2018 (19)	NA	Self-administered questionnaire	Brazil	489 respondents	Cross-sectional	Prevalence of EC use: - Ever use = 2.7%	High numbers of ever EC user
Kalkhoran et al., 2018 (20)	Smoke-free Support Study	Secondary cross-sectional analysis of baseline enrolment data	US	302 adults (age ≥18 years) diagnosed with cancer	Cross sectional	Prevalence of: - Ever users = 49% - Current EC users = 19%	High numbers of ever EC user
Bao et al.,2018 (21)	National Health Interview Survey (NHIS)	In-person survey	US	101175 participants (noninstitutionalized, civilian US population)	Cross-sectional in prospective cohort study	Prevalence of ever used: - 2014 = 12.6% - 2015 = 13.9% - 2016 = 15.3%	Numbers of ever EC users increased over the years

Hu et al., 2019 (22)	Behavioral Risk Factor Surveillance System (BRFSS) 2016	Telephone survey	US	477,665 respondents	Cross-sectional	Prevalence of EC use: - Ever use = 16.2% to 28.4% - Current use = 2.4% to 6.7%	Increased numbers of ever and current EC users
Owens, Ha & Soulakov, 2019 (23)	Tobacco Use Supplement to the Current Population Survey (TUS-CPS) 2014-2015	Self-administered questionnaire	US	- 5,503,817 EC users - 1,331,394 hookah tobacco users	Cohort	Smoking status of EC users: - Non-smoker = 8.3% - Ex-smoker = 26.1% - Current smoker = 65.6%	High numbers of dual users who were currently smoked CC
Du, Shih, Shah, Weber & Lightstone, 2019 (24)	LA County Health Survey 2015	Telephone survey	US	8,008 respondents	Cross-sectional	Prevalence of EC use: - Ever use = 8.4%	-
European Region							
Brown et al., 2014 (25)	NA*	On-line survey	Great Britain	- 3,538 current - 579 recent ex-smokers	Cross sectional	Prevalence of: - Current use = 21% - Ever used = 37%	High numbers of ever EC users
Vardavas, Filippidis & Agaku, 2015 (26)	Special Eurobarometer 385 (77.1) 2012	Self-administered questionnaire	27 EU members	- 26,566 respondents	Cross-sectional	Overall prevalence of EC user: - Ever used = 20.3%	High numbers of ever EC users
Andler et al., 2016 (27)	2014 Health Barometer	Telephone survey	France	15,635 individuals (15 – 75 years old)	Cross sectional	- Had tried EC = 25.7%; consisted of 23.4% current users	High numbers of ever EC users
Filippidis, Laverty, Gerovasili &Vardavas, 2017 (28)	Adult Special Eurobarometer for Tobacco survey 2012 & 2014	Interview session	27 European Union member states	- 2012 (n = 26, 751) - 2014 (n = 26, 792)	Cross sectional	Prevalence of ever use of EC: - 2012 (7.2%) - 2014 (11.6%)	Numbers of ever users increased over the years
Ruokolainen, Ollila & Karjalainen, 2017 (29)	NA	Self-administered anonymous online/ postal questionnaire	Finland	7000 respondents (15–69 years)	Cross sectional	Prevalence of: - Ever EC users = 12% - Current EC users = 2%	High numbers of ever EC users
Brożek et al., 2017 (30)	NA	Self-administered questionnaire	Poland	1,318 medical students	Cross-sectional	Prevalence of EC use: - 1.3% (consisted of 2.2% dual users)	High numbers of dual users
Balogh et al., 2018 (31)	NA	Self-administered questionnaire	Germany and Hungary	2,925 medical students	Cross-sectional	Prevalence of EC use = 0.9%	-
East, Brose, Mcneill, Cheesema, & Hitchma, 2019 (32)	Action on Smoking and Health (ASH) Smokefree Great Britain Youth survey 2016	Self-administered questionnaire	Great Britain	2,103 respondents	Cross-sectional survey	Prevalence of: - Ever use = 11.28% - Current use = 1.62%	High numbers of ever EC user
Western Pacific Region							
IPH, 2016 (33)	National E-Cigarette Survey 2016	Interview session	Malaysia	4288 adults	Cross sectional	Prevalence of: - Current EC user = 3.2% - Ever use = 11.9% - Dual user = 2.3%	High numbers of ever EC user
Wong, Mohamad Shakir, Alias, Aghamohammad, & Hoe, 2016 (34)	NA	Self-administered survey	Malaysia	429 respondents	Cross-sectional	Prevalence of EC users among: - College/universities' student = 39.4% - Professional and managerial = 36.4% - Skilled/non-skilled workers = 23.5%	High numbers of EC users among young adults

Jiang et al., 2016 (35)	2014 Hong Kong Tobacco Control Policy-related Survey	Computer-assisted telephone interviews	Hong Kong	809 respondents - 357 never smokers - 269 former smokers - 183 current smokers	Cross sectional	Prevalence of: - having used EC= 2.3%	High numbers of ever EC user
Cheung et al., 2017 (36)	Hong Kong Tobacco Control Policy-related Survey	Telephone-based survey	Hong Kong	5,252 adults (≥15 years old) - never smoke = 1706 - ex-smokers = 1712 - smokers = 1834	Cross sectional	Prevalence of: - Ever use = 0.7% - Current use = 0.2%	High numbers of ever users
Chang, Tsai, Shiu, Wong, & Chang, 2017 (37)	Taiwan Adult Smoking Behaviour Survey 2015	Computer-assisted telephone survey	Taiwan	2,6021 adults (≥15 years old)	Cross sectional	Prevalence: - Had ever used = 3%	High numbers of ever EC user
Kioi & Tabuchi, 2018 (38)	NA	Online survey	Japan	4,432 respondents	Cross-sectional	Prevalence of EC use: - Ever use = 7.6% - Current use = 0.4%	High numbers of ever EC user
Wan Puteh et al., 2018 (39)	NA	Self-administered survey	Malaysia	1,302 universities' students	Cross-sectional	Prevalence of EC users: - Dual users = 40.3% - Never-smoked users = 20.4% - Ex-smokers = 14.1%	High numbers of dual EC users
Oakly & Martin, 2019 (40)	Health and Lifestyles Survey (HLS) 2016	Face- to-face in-house survey	New Zealand	3,854 respondents	Cross-sectional	Prevalence of EC use: - Current use = 3.1%	-
Gravely et al., 2014 (41)‡	International Tobacco Control (ITC) surveys	Interview session via phone or face-to-face interviews &Online survey	10 countries: - China - UK - US - Canada - Republic of Korea - Malaysia - Mexico - Brazil - Netherlands	20, 411 samples of adults (≥ 18 years old) who are current and former smokers	Cross sectional	Percentage of current user of EC among conventional cigarette smoker (Top 5): - Malaysia = 15% - Republic of Korea = 7% - USA = 6% - UK = 5% - Canada = 2%	High numbers of dual EC users
Palipudi et al., 2016 (42)‡	Global Adult Tobacco Surveys	Face-to-face interview session	4 countries include: i. Malaysia ii. Indonesia iii. Greece, iv. Qatar	Adult respondents - Indonesia = 8305 - Malaysia = 4250 - Qatar = 8389 - Greece = 4357	Cross sectional	Prevalence of current use: - Malaysia = 0.8% - Indonesia = 0.3% - Qatar = 0.9% - Greece = 1.9%	High numbers of current EC users

**Conventional cigarette;*

‡studies conducted in multiple countries

European Region

Overall, there were 8 articles in this review which involved European countries namely the United Kingdom (UK), Germany, Hungary and Poland (25-32). According to the European Eurobarometer Survey 2012 and 2014, the two-year trend of EC used in 27 European Union (EU) member states was published and the report showed that there were a significant increase in the prevalence of ever users from 7.2% (95% CI 6.7-7.7%) in 2012 to 11.6% (95% CI 10.9-12.3) (28). Specifically, the prevalence of ever users reported in 2014 was widely varied across countries in which Portugal has shown to have the lowest prevalence (5.7%) while the highest prevalence of ever EC users was reported in France (21.3%).

Furthermore, there are three population-based studies which have been conducted among adults in the Great Britain (32), Finland (29) and France (27). The recent data on the prevalence of ever and current EC users reported among Finnish adults were slightly higher (12%, n = 840; 2%, n = 140, respectively) (29) than Great Britain (11.28%, n = 274; 1.62%, n = 33, respectively) (32) but lower than the prevalence of EC use in France (25.7%, n = 4018; 6%, n = 938, respectively) (27). However, the earliest published data by Brown and colleagues (2014) (25) have shown the greater number of current and ever EC users among adults in Great Britain (37%, n = 1523; 21%, n = 865, respectively) compared with the recent data by East and colleagues (2018) (24) (11.28%, n = 274; 1.62%, n = 33, respectively).

Western Pacific Region

The large number of EC users among the general population of the Western Pacific Region including Malaysia (33), Japan (38), Taiwan (37), New Zealand (40) and Hong Kong (36) have been shown in several studies (33-40). Among these studies, Malaysia has the highest prevalence of current EC users which accounted for 3.2% (n = 137) (33), followed by New Zealand (3.1%, n = 117) (40), and Hong Kong (0.2%, n = 11) (36). Compared with the proportion of ever EC users reported in Taiwan (2.7%, n = 703) (37) and Hong Kong (2.3%, n = 41; 0.7%, n = 37) (35, 36), the percentage of ever EC users reported in the Malaysian national representative study on EC (known as the National Electronic Cigarette Survey 2016 were highest (11.9%, n = 510) (33).

Similar with the American region, the existence of dual user has also been reported among the these countries (35-37,40). This review found that the proportion of dual user who used EC and smoked conventional cigarette simultaneously was higher than the exclusive EC users being reported in New Zealand (63.9%, n = 90 vs 36.1%, n = 27, respectively) (40), Taiwan (14.2%, n = 365 vs 4%, n = 278, respectively) (37) and Hong Kong (1.7%, n = 29 vs 0.7%, n = 28, respectively) (36). Table 1 summaries the studies that included in this review.

DISCUSSION

Principal finding

To our knowledge, this is the first study that highlights the trend of EC use among adult population in multiple countries across regions. Based on the findings of this review, there are few significant issues identified due to the increased popularity of EC among the world population as reported in many countries. Firstly, regardless of regions, similar trends of use have been shown among adult population in which EC have been widely used among current conventional cigarette smokers (dual user). Secondly, even though the initial aim of EC invention was to assist smokers to stop smoking, high numbers of EC users have been reported among young non-smoking population who likely used the device for recreational purposes.

While exploring the trend of EC use across regions in all included articles, a similar pattern of use in regard to the percentage of ever EC users and current EC users have been reported (21,22,28,35,36). Higher number of ever EC users than current EC users shown in multiple studies portrayed the experimentation use of the device by ever users and the discontinuation of use, therefore, making the number of current users to drop. On the other hand, the findings of two-year surveillance study of Eurobarometer Survey (2012-2014) have highlighted that one-fifth of ever users will end up as a current EC user in the latter year (28). Eagerness to try this newly invented nicotine-delivery device may contribute to the occurrence of this scenario.

There are multiple studies conducted in the American (10,13,21) and the European region (28) which assessed the trend of EC use within consecutive years. The significant increment in the prevalence of EC users has been reported in the US by four-fold in 2010 (2.7%) compared to 2009 (0.6%). The involvement of non-smoking users who tend to use EC in the latter years have been said to contribute to this increment [8.3% of never-smoked EC user (23) and 3.5% (24) of never-smoked EC user].

Furthermore, there were several significant socio-demographic characteristics of adult population which have been identified to contribute to the increase of EC user prevalence. Young adults (18 to 24 years old) were 12 times more likely to be an ever EC users compared to the older age adult (24). While, those who attained a tertiary educational level and economically stable were two times more likely to experiment the device (24). By addressing the socio-demographic

disparities (younger vs older adult; tertiary educational level vs counterparts) of EC users, this may provide the health authority with a targeted-group approach in their public health advocacy activities. These determinants may also be considered during the development of evidence-based health promotion programs to curtail the EC-related issue in the general population.

One of the most cited reasons of EC use was to quit smoking (20, 43). However, this creates the emergence of dual-user group who likely used EC and conventional cigarette simultaneously to deal with nicotine withdrawal effects. These have been reported by a few studies conducted in the American Western Pacific regions (36,37,40). To some extent, studies revealed that being a conventional cigarette smoker was the main predictor for a person to try EC (14, 26). Due to inconclusive evidence on the efficiency of EC as a smoking cessation tool, dual users have the potential to either i) stop smoking conventional cigarette and continue the use of EC or ii) remain as a dual user (44, 45). Even though a smoker has stopped smoking conventional cigarettes, the exposure to nicotine and other chemicals remained via the use of nicotine-containing e-liquids. There is also the possibility of dual users to continually use EC and conventional cigarettes to circumvent the non-smoking policy in a place where smoking is prohibited.

Strengths and Limitations

This systematic review followed the reporting standards of the PRISMA checklist. Apart of that, a substantial search was performed on published literature within the first seven years (2013-2019) after the EC markets have been well-established in developed and developing countries. Nonetheless, this study had several limitations. Firstly, as this review only included English written articles, some relevant articles may not be covered in this review. Secondly, as this review addressed the review of findings across multiple studies, however we unable to perform a meta-analysis which will produce further which will be more of benefits to policy makers. This was due to variability in study designs and different target groups of study population.

CONCLUSION

This review was able to identify certain similar trend on the distribution of EC user across regions. The emergence of dual user group and the involvement of EC users who previously never-smoke must be treated as a public health concern. The widespread use of EC especially among those who never smoke before threaten the tobacco control strategies and planning which were implemented to reduce the numbers of tobacco users as well as preventing smoking initiation among young population. Therefore, a continued surveillance on EC use should be performed on a regular basis as the rapid technological advancement of the device and e-liquid formulation may pose a significant public health risk.

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