The Egyptian Journal of Internal Medicine

RESEARCH

Open Access

A comparison of electrocardiographic parameters in e-cigarette users, conventional cigarette smokers, and non-smokers

Heba Ammar[1*], Rania Hashish[1], Shrouk Mohamed Ali[1], Ahmed Salah Salem[2] and Abeer Mohamed Hagras[1]

Abstract

Background Smoking is a major preventable risk factor for cardiovascular morbidity and mortality. Tobacco smoking induces atherosclerosis, ischemic heart diseases, and arrhythmias. The impact of electronic cigarettes on cardiovascular health is still controversial. This study aimed to evaluate the electrocardiographic parameters in chronic electronic cigarette users compared to chronic conventional cigarette smokers and a non-smoker control group of matched age and gender.

Results The study involved 105 volunteers with no history of chronic or cardiovascular diseases or cardioactive drug use. Participants were assigned into three study groups, chronic e-cigarette users, conventional cigarette smokers, and non-smokers, each consisting of 35 participants. Demographic data, smoking history, vital signs, and 12-lead electrocardiogram (ECG) were evaluated. Demographic data were insignificantly different among all study groups. The mean heart rate was significantly higher in chronic electronic cigarette users and conventional cigarette smokers compared to non-smokers ($p < 0.001$).QRS complex duration was significantly shorter in e-cigarette users and conventional smokers compared to non-smokers ($p < 0.001$). Prolonged QT and QTc intervals duration were recorded in e-cigarette users and conventional smokers compared to non-smokers ($p < 0.001$). All the ventricular repolarization indices (*T* wave—peak to T-end (Tpe) interval, TPe/QT ratio, and TPe/QTc ratio were significantly prolonged in chronic e-cigarette users, and conventional smokers compared to non-smokers ($p < 0.001$). Mean systolic, diastolic blood pressure, *P* wave amplitude and duration, and PR interval were insignificantly different between all groups ($P > 0.05$).

Conclusions Chronic e-cigarette use is associated with higher heart rates, shorter QRS complex, prolonged QT, QTc duration, and prolonged ventricular repolarization indices compared to non-smokers of matched age and gender. Conclusively, e-cigarette use is associated with negative cardiovascular effects like conventional cigarette smoking.

Keywords Electronic cigarettes, Vaping, Conventional cigarettes, Fagerstrom test for nicotine dependence, Nicotine, Tobacco, Electrocardiogram, Ventricular repolarization parameters

Background

Tobacco smoking is the most preventable cause of morbidity and mortality worldwide [1]. Tobacco smoking induces atherosclerosis, ischemic heart diseases, and arrhythmias. Cardiovascular diseases represented the main burden of disease in the Middle East in the past 30 years and are a major cause of mortality [2].

*Correspondence:
Heba Ammar
heba_ammar@med.suez.edu.eg; hebaammar_2010@yahoo.com
[1] Department of Forensic Medicine and Clinical Toxicology, Faculty of Medicine, Suez Canal University, Ismailia, Egypt
[2] Department of Cardiology, Faculty of Medicine, Suez Canal University, Ismailia, Egypt

Springer Open

© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

Electronic cigarettes (e-cigarettes), also known as vaping devices, have gained significant popularity as an alternative to traditional tobacco smoking. E-cigarettes were introduced to markets in 2007, and since then, it was promoted as a safer alternative to conventional cigarettes. Furthermore, it is advertised by manufacturers as a method to quit smoking with minimal or no harmful effects and it is commonly used as a trendy smoking technique among youth [3, 4].

While e-cigarette use is often considered less harmful than conventional combustible cigarette smoking, the clinical effects of e-cigarettes on cardiovascular health remain inadequately understood. Hence, concerns have been raised regarding e-cigarette use and its potential cardiovascular negative impacts, including effects on cardiac electrophysiology and alterations in ventricular repolarization [5].

Numerous studies have evaluated the impact of conventional cigarette smoking on ECG parameters, demonstrating adverse effects on the ECG profile of smokers. To date, only a limited number of studies have investigated the impact of chronic e-cigarette smoking on ECG parameters, and the results have been inconsistent [6, 7].

Cardiovascular health is one area of concern due to the potential for e-cigarette aerosols to contain nicotine, propylene glycol, toxic chemicals, and ultrafine nanoparticles, which can have adverse effects on the myocardium and cardiac conductivity [8]. Several studies have reported changes in cardiac function associated with e-cigarette use. However, the available data regarding the impact of e-cigarettes specifically on ECG parameters and ventricular repolarization indices remains scarce [9, 10].

The electrocardiogram (ECG) is a routine, non-invasive, inexpensive, tool for assessment of cardiovascular disease and its risks, in both clinical and research settings. Hence, the ECG can be used as a reliable tool to assess the cardiac effects of nicotine and other components of e-cigarette aerosol on the heart [11].

Major and minor ECG changes powerfully predict increased cardiovascular morbidity and mortality in the general healthy population. Moreover, ECG interpretation is a basic skill attained by all general practitioners and is easily interpreted by most clinicians, widely available in all health care centers, making it a powerful screening method for the cardiovascular function [12].

Novel ECG indices to assess ventricular repolarization are extensively used in recent research as Tpe, Tpe/QT, and Tpe/QTc [13]. The Tpe interval is the duration between the peak and end of the T wave. Prolonged Tpe intervals may provoke periodic ventricular arrhythmias and predispose to sudden cardiac death [14].

Previous research showed an association between increased mortality and prolongation of Tpe interval in Brugada syndrome, long QT syndrome, and hypertrophic cardiomyopathy [15]. So, this study aimed to evaluate the electrocardiographic parameters in chronic electronic cigarette users compared to chronic conventional cigarette smokers and the non-smoker control group of matched age and gender.

Previous research was conducted to determine the cardiovascular effects of conventional cigarettes. However, published data regarding the cardiovascular effects of e-cigarettes is scarce despite its increasing use [8, 16]. The current study aimed to compare the electrocardiographic parameters in chronic electronic cigarette users, conventional cigarette smokers, and non-smokers.

Methods

This is a comparative, cross-sectional study that was conducted from January 2020 to January 2021. A total of 105 healthy volunteers were enrolled, with 35 participants each study group.

The participants were apparently healthy volunteers who were gathered through convenient sample and snowball technique and recruited according to the exclusive use of either e-cigarettes or conventional cigarettes. A structured questionnaire was designed and filled by the principal investigator for each participant through a face-to-face interview. The research questionnaire was anonymous to assure the reliability and validity of collected data regarding smoking behavior (i.e., either exclusively using e-cigarettes, conventional cigarettes, or dual smokers).

Participants were guaranteed to provide real answers by following ethical guidelines regarding privacy and confidentiality of data, and anonymity of the research questionnaire in addition to repeated questions about the smoking behavior as participants are more honest towards behavioral structured questions which will ensure the validity of provided answers.

Participants were categorized into three study groups according to their smoking status. Group 1 included 35 exclusive chronic e-cigarette users who are using e-cigarettes exclusively for more than 12 months according to DSM-V criteria for diagnosing nicotine dependence, group 2 included 35 exclusive chronic conventional cigarette smokers who are smoking conventional cigarettes exclusively for more than 12 months according to DSM-V criteria of diagnosing nicotine dependence, and group 3 control group of 35 healthy non-smokers of matched age and gender. A chronic e-cigarette user or chronic conventional cigarette smoker according to the DSM-5 is defined as any individual who is used to the habit of daily smoking for more than 12 months [17, 18].

Table 1 Demographic characteristics of the three study groups ($N=105$)

Demographic characteristics	Group 1 ($n=35$)	Group 2 ($n=35$)	Group 3 ($n=35$)	*p* value
Age				
• ≤ 20 years	6 (17%)	2 (6%)	2 (6%)	0.2[$]
• > 20–40 years	27 (77%)	29 (83%)	27 (77%)	
• > 40 years	2 (6%)	4 (11%)	6 (17%)	
Gender, (females/males %)	12/23 (34/66%)	13/22 (37/63%)	14/21 (40/60%)	0.962[x]
Scholastic attainment (middle/high)	13/22	8/27	12/23	0.422[x]

Group 1: Electronic cigarette users

Group 2: Conventional cigarette smokers

Group 3: Non-smokers control group

[$] One-way ANOVA

[x] Chi-square test

Those who were dual smokers (currently smoke both conventional and electronic cigarettes) and other tobacco product users (i.e., Hookah, tobacco chewing, nicotine gum, bidis, snuff, pipe, or cigars) were excluded from the study due to variable nicotine concentrations in these products. Additionally, individuals with a history of chronic diseases, e.g., hypertension, diabetes mellitus, cardiac, respiratory, renal, or endocrine disorders or using concomitant cardioactive medications or abusing illicit psychoactive substances were also excluded from the current study.

The study fulfilled Helsinki's declaration, the purpose and procedure of the study were explained to all participants, and the study was approved by the full board of institutional research ethics committee at its meeting on November 25, 2019 (Reference number: 4014#). All participants signed a written informed consent. Participants' privacy as well as the confidentiality of their data were protected.

Statistical analysis

The data were statistically analyzed by Statistical Package for Social Science (SPSS) version 22 (SPSS Inc, Chicago, Ill., USA). Continuous variables were expressed as means and standard deviation (S.D.). Categorical variables were presented as frequencies and percentages. Continuous variables were compared between the three study groups by the one-way analysis of variance (ANOVA) test while categorical variables were compared by chi-square test. Independent sample Student's *T* test was used to compare means of continuous variables between e-cigarettes and conventional cigarette smoker groups. Correlation analysis was performed via Pearson's correlation analysis. All statistical tests were two-sided, and a p value of < 0.05 was considered significant.

Results

This comparative study was conducted on 105 volunteers with age ranges from 19 to 57 years old, mean = 31.16 ± 10.65 years with male gender predominance (58 males, 55.2% of participants) compared to (47 females, 44.8% of sample). There was no significant difference between the three study groups regarding demographic data (P value > 0.05) (Table 1).

Regarding smoking history, a comparison of smoking indices between e-cigarette users and conventional cigarette smokers was of no statistical significance ($p > 0.05$). On the contrary, the conventional cigarette users group had a statistically significant longer duration of smoking and higher scores in the Fagerstrom test of nicotine dependence (FTND) ($p < 0.001$) (Table 2).

Regarding types of smoking products used by both smoker groups, it was found that the e-cigarette user group reported using e-liquids of variable nicotine strength ranging from nicotine content of 30–60 mg/ml, in addition to flavorings, glycerin, propylene glycol, and diethylene glycol.

While the conventional cigarette smoker group reported using local and imported tobacco cigarettes of medium strength, which contained nicotine concentration of (10–20 mg/cigarette), Tar, CO, formaldehyde,

Table 2 Smoking history among electronic cigarette users and conventional cigarette smokers ($N=70$)

Smoking history (mean ± SD)	Group 1 ($n=35$)	Group 2 ($n=35$)	*p* value
Smoking index (pack years)	20.5	17.7	0.222[t]
Smoking duration (years)	2.2 ± 0.7	3.7 ± 1.5	< 0.001[*t]
Severity of nicotine dependence (FTND score), no. (%)			
• Moderate dependence	15 (42.9%)	0 (0%)	< 0.001[*x]
• High dependence	20 (57.1%)	35 (100%)	

Group 1: Electronic cigarette users

Group 2: Conventional cigarette smokers

FTND Fagerstrom test of nicotine dependence

[*] Statistically significant at p value < 0.05

[t] Student's T-test

[x] Chi-square test

Table 3 Comparison of the clinical vital signs among the three study groups ($N=105$)

Vital signs (mean ± SD)	Group 1 ($n=35$)	Group 2 ($n=35$)	Group 3 ($n=35$)	*p* value between the three groups	*p* value between males and females	*p* value between group 1 and group 2	*F* test
Heart rate (bpm)							
Total	71.7 ± 9.2	73.4 ± 5.2	64.2 ± 3.4	< 0.001[*$]	0.54	0.26[#]	11.75
Males	68.4 ± 6.5	73.5 ± 4.7	64.5 ± 3.6				
Females	76 ± 10.7	73.2 ± 5.9	63.9 ± 3.01				
Systolic blood pressure (mmHg)							
- Total	115.7 ± 5.4	114.9 ± 5.6	114.3 ± 5.2	0.537[$]	0.96	0.55[#]	71.4
- Males	114.5 ± 5.1	118.8 ± 9.5	114.7 ± 5.1				
- Females	114.7 ± 5.2	115.6 ± 9.6	113.8 ± 5.01				
Diastolic blood pressure (mmHg)							
- Total	75.4 ± 9.2	78.8 ± 8.9	70.6 ± 8.8	0.736[$]	0.78	0.84[#]	0.5
- Males	78.5 ± 5.4	79.5 ± 9.1	70 ± 9.7				
- Females	69.3 ± 7.3	71.9 ± 8.5	67.2 ± 5.4				
Body mass index (BMI)							
- Total	23.6 ± 1.9	22.6 ± 2	25.02 ± 1.1	0.9[$]	0.85	0.7[#]	12.29
- Males	23.4 ± 2.1	22.3 ± 2	23.4 ± 2.4				
- Females	23 ± 1.6	22.9 ± 1.9	23.9 ± 1.4				
Oxygen saturation (SpO_2)							
- Total	97.91 ± 0.3	97.75 ± 0.5	98.12 ± 0.15	0.09[$]	0.06	0.8[#]	4.63
- Males	97.82 ± 0.45	97.42 ± 0.57	98.92 ± 0.27				
- Females	97.96 ± 0.18	97.67 ± 0.36	99.11 ± 0.12				

Group 1: Electronic cigarette smokers

Group 2: Conventional cigarette smokers

Group 3: Non-smokers control group

[*] Statistically significant at *p* value < 0.05

[$] One-way Anova

[#] LSD post-hoc test

polycyclic aromatic hydrocarbons, and tobacco-specific nitrosamines.

The clinical vital signs among the three study groups are shown in Table 3. Comparing means of heart rates between e-cigarette users (71.71 ± 9.23) and conventional cigarette smokers (73.43 ± 5.2) showed no statistical significance. However, heart rate was significantly higher in both smoker groups compared to non-smokers (64.23 ± 3.4).

Regarding systolic, diastolic blood pressure, body mass index, and oxygen saturation, no statistically significant difference was shown between the three study groups. However, it is shown that diastolic blood pressure is increased in the e-cigarette user group and conventional cigarette smokers compared to the non-smoker control group.

Electrocardiographic parameters of all three study groups are represented in (Table 4). All participants had sinus rhythm. The mean QRS complex duration in milliseconds showed a similar significant shortening in both electronic cigarette users and conventional cigarette smoker groups compared to non-smokers (88.86 ± 9.3, 87.7 ± 9.4, 100.57 ± 6.8), respectively ($P<0.001$).

Conversely, the mean duration of QT interval in milliseconds showed a similar significant prolongation in both electronic cigarette users and conventional cigarette smokers groups compared to non-smokers (360 ± 17.6, 361.22 ± 14.2, 343.7 ± 24.3), respectively ($P<0.001$). Similarly, the mean duration of QTc interval in milliseconds showed a similar significant prolongation in both electronic cigarette users and conventional cigarette smoker groups compared to non-smokers (390.9 ± 13.16, 394.86 ± 16.19, 385 ± 13.16), respectively ($P<0.001$).

All ECG parameters of ventricular repolarization indices (Tpe, Tpe/QT, and Tpe/QTc) showed a similar significant prolongation in e-cigarette users and conventional cigarette smokers compared to the non-smoker control group ($P<0.001$).

Regarding *P* wave duration, amplitude, and PR interval duration, differences were of no statistical significance between the three study groups.

Table 4 Electrocardiographic (ECG) parameters among the three study groups ($N = 105$)

Variable (mean ± SD)	Group 1 ($n = 35$)	Group 2 ($n = 35$)	Group 3 ($n = 35$)	*p* value between Group 1, Group 2, and Group 3	*p* value between Group 1 and Group 2	*F* test
P wave amplitude (mv)	0.251 ± 0.001	0.249 ± 0.004	0.25 ± 0.003	0.37[$]	0.9[#]	1
P wave duration (ms)	114.6 ± 7.8	111.4 ± 12.16	108 ± 15.1	0.08[$]	0.223[#]	2.6
P-R interval (ms)	126 ± 8.1	126.57 ± 8.7	127.71 ± 9.1	0.702[$]	0.279[#]	0.35
QRS complex(ms)	88.86 ± 9.3	87.7 ± 9.4	100.57 ± 6.8	< 0.001[*$]	0.580[#]	23.9
QT interval	360 ± 17.6	361.22 ± 14.2	343.7 ± 24.3	< 0.001[*$]	0.783[#]	22.751
QTc interval(ms)	390.9 ± 13.16	394.86 ± 16.19	385 ± 13.16	< 0.001[*$]	0.633[#]	51.4
Tpe interval (ms)	83.2 ± 6.6	85.5 ± 4.3	78.86 ± 5.2	< 0.001[*$]	0.85[#]	188.7
TPe/QT ratio	0.23 ± 0.01	0.25 ± 0.02	0.2 ± 0.03	< 0.001[*$]	0.79[#]	250.9
TPe/QTc ratio	0.21 ± 0.02	0.23 ± 0.03	0.19 ± 0.02	< 0.001[*$]	0.76[#]	964.5

Group 1: Electronic cigarette smokers

Group 2: Conventional cigarette smokers

Group 3: Non-smokers control group

[*] Statistically significant at p value < 0.05

[$] One-way Anova

[#] LSD post-hoc test

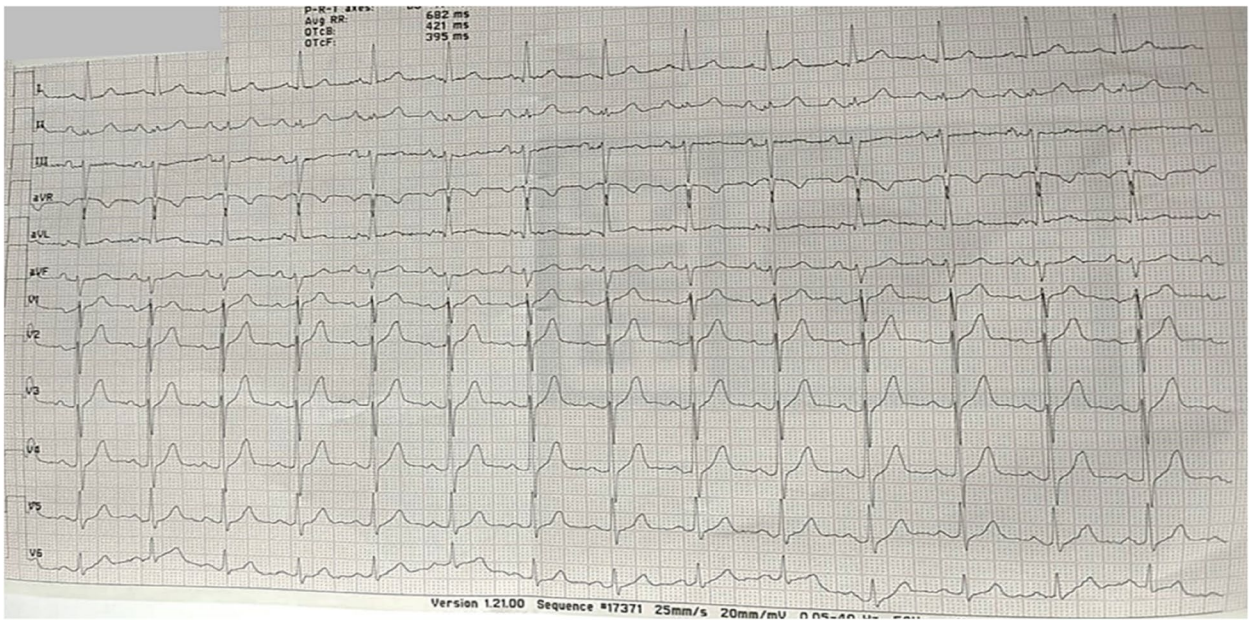

Fig. 1 ECG tracing of an e-cigarette user showing sinus rhythm (87 bpm), QT (348 ms), and QTc (420 ms)

ECG parameters such as QRS, QT, QTc, Tpe, Tpe/QT, and Tpe/QTc were no statistically significant difference between e-cigarette users and conventional cigarette smokers ($p > 0.05$). However, these parameters differed significantly between e-cigarette users and the non-smoker control group and between conventional cigarette smokers and the non-smoker control group ($p < 0.001$).

A sample of the recorded ECG tracings in the current study is illustrated in Figs. 1 and 2, which display ECG tracing for an electronic cigarette user (Fig. 1) and another ECG tracing of a conventional cigarette smoker (Fig. 2).

Table 5 shows correlation analysis was performed using Pearson's bivariate correlation coefficient between smoking index, smoking duration (as independent variables),

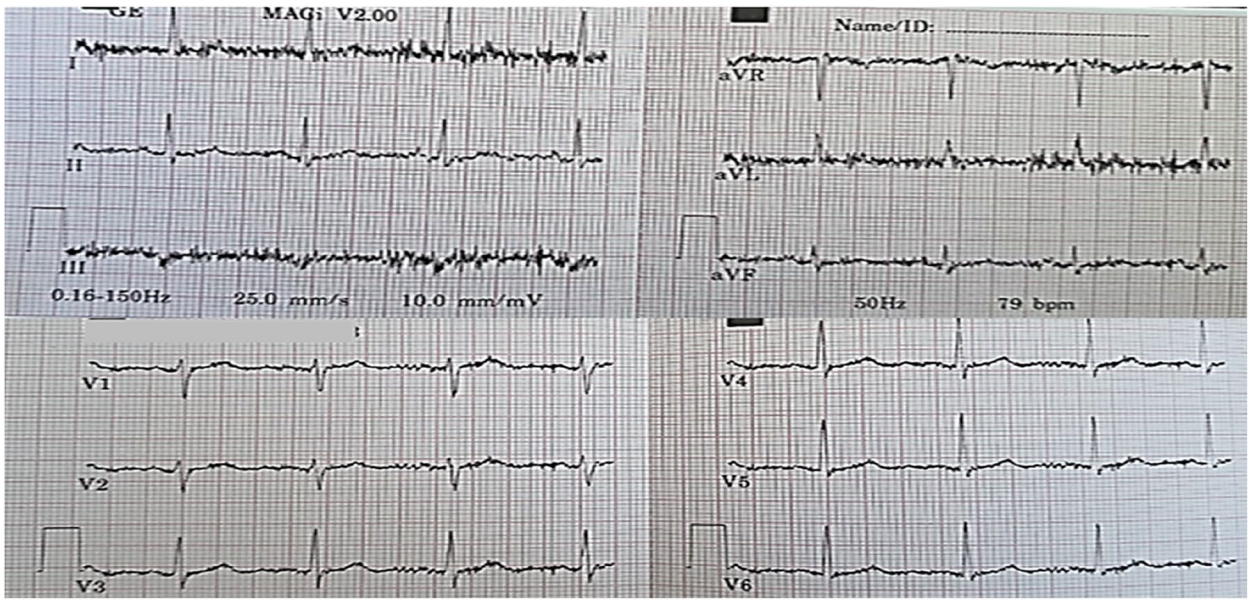

Fig. 2 ECG tracing of a conventional cigarette smoker showing sinus rhythm (79 bpm), QT (390 ms), and QTc (450 ms)

and the reported ECG parameters in the e-cigarette user group and conventional cigarette smoker group (as the dependent variables). Neither the smoking index nor the smoking duration had a significant correlation with the reported ECG parameters of both the e-cigarette user group and conventional cigarette smoker groups, $p > 0.05$.

Discussion

According to the current knowledge little is known about the cardiovascular effects of e-cigarette use which may not be risk-free. The chemical composition of e-cigarette aerosol contains propylene glycol, glycerin, nicotine, flavors, aroma transporters, and other substances. The levels of nicotine, tobacco-specific nitrosamines (TSNAs), aldehydes, metals, volatile organic compounds (VOCs), flavors, and tobacco alkaloids in e-cigarette aerosols vary greatly. Hence, chronic use of e-cigarettes may potentially impact health [19].

The major new finding in this study is the prolonged ventricular repolarization indices in chronic e-cigarette users, which may predispose to fatal ventricular arrhythmias and sudden cardiac death just similar to the previously documented risks of conventional cigarette smoking [20].

In the present study, the mean heart rate of chronic e-cigarette and conventional cigarette smokers was higher compared to non-smokers. This is in concordance with similar past studies conducted on chronic combustible cigarette smokers and can be attributed to the presence of nicotine in both electronic cigarettes and conventional cigarettes consumed by the participants [20–22].

In the present study, neither the systolic blood pressure (SBP) nor the diastolic blood pressure (DBP) showed any significant differences between the three study groups.

In concordance with our results, past similar studies by Bayramoğlu et al. and Lan et al. stated that no correlation was found between cigarette smoking and blood pressure after adjustment for age, BMI, and physical activity [22, 23].

A possible explanation for the similarity in blood pressure levels between smokers and non-smokers in the present study could be due to adaptation or rebound effect. Blood pressure is one vital parameter that lies under a tight physiological control mechanism of homeostasis [24].

Regarding *P* wave amplitude and duration and P-R interval, there was no significant differences between the three study groups. This may be attributed to the less evident effects of nicotine on atrial electrical activity and atrial conduction. This agrees with previous studies about the effect of conventional cigarette smoking on ECG, in which *P* wave, and P-R interval were similar between smokers and non-smokers [25–27].

Regarding QT and QTc interval, the current study showed a statistically significant prolongation of QT and QTc interval among e-cigarettes and conventional cigarette smokers compared to non-smokers which is consistent with previous studies by Özdemir et al. and Demir et al. who reported prolonged QTc duration in chronic cigarettes smoking compared to non-smokers [26, 28].

Table 5 Correlation between smoking index, smoking duration, and ECG parameters in both smoker groups (e-cigarette users and conventional cigarette smokers)

		ECG parameters								
		***P* wave amplitude**	***P* wave duration**	**QRS**	**PR**	**QT**	**QTc**	**Tpe**	**Tpe/qt**	**Tpe/qtc**
Smoking index (*N* = 70)	***r*[a]**	**0.07**	**0.04**	**0.18**	**0.12**	**0.14**	**0.05**	**0.12**	**0.12**	**0.01**
	p value	0.56	0.72	0.13	0.31	0.23	0.67	0.33	0.34	0.94
Smoking duration (*N* = 70)	***r*[a]**	**− 0.11**	**− 0.12**	**− 0.07**	**0.19**	**0.11**	**0.05**	**− 0.08**	**− 0.08**	**0.04**
	p value	0.35	0.31	0.55	0.10	0.37	0.71	0.49	0.49	0.97

[a] *r* Pearson correlation coefficient

Prolonged QTc duration is a recognized predictor of ventricular arrhythmias and a predisposition to sudden cardiac death. A recent study conducted by Tokgozoglu et al. deducted that chronic smoking may induce coronary vasoconstriction, ST elevated myocardial infarction (STEMI) ischemia, and various ventricular arrhythmias as a result of QT abnormalities [29, 30].

The current study showed that all the ventricular repolarization indices (Tpe, Tpe/QT, and Tpe/QTc ratios) were similarly prolonged in e-cigarette users and conventional cigarette smokers compared to non-smokers which is consistent with past research results by Demir et al. and Tokgozoglu et al. in which prolonged ventricular repolarization indices in chronic conventional cigarettes smoking compared to non-smokers was reported [28, 29].

Previous research showed an association between increased mortality and prolongation of Tpe interval in Brugada syndrome, long QT syndrome, and hypertrophic cardiomyopathy [15].

Thus, the considerable TPe interval prolongation in the e-cigarette user group is considered an indirect measurement of repolarization time dispersion and correlated with the risk of ventricular arrhythmogenesis. The TPe/QT ratio is regarded as a more sensitive marker of liability to arrhythmia as it is not dependent on differences in body weight or heart rate [13, 15].

The ventricular repolarization indices, Tpe interval, Tpe/QT, and Tpe/QTc ratio are ECG parameters and calculated ratios that correlate with ventricular diastolic dysfunction and show better predictive values for ventricular arrhythmias than traditional parameters such as QT interval. The altered ventricular electrical activities predispose chronic smokers to episodes of ventricular arrhythmias, torsade de pointes, and sudden cardiac death [28].

The current findings provide evidence for the negative impacts of e-cigarette use on electrical cardiac activity. E-cigarette use impacts cardiovascular function just like the conventional cigarette smoking does. The main limitation of our study was its cross-sectional design that cannot establish a cause-and-effect relationship.

Conclusions

The current study concluded that both chronic e-cigarette users and conventional cigarette smokers have electrocardiographic patterns that are significantly different from that of non-smokers of matched age and gender. Chronic electronic cigarette use increases heart rates, prolongs QT, QTc interval duration, and all ventricular repolarization indices similar to chronic conventional cigarette smoking. Conclusively, e-cigarette use should be considered a novel threat to cardiovascular health, and it is better advised to quit all types of smoking.

Abbreviations

E-cigarettes	Electronic cigarettes
ECG	Electrocardiogram
mg	Milligram
ml	Millilitre
DSM-V	The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
HR	Heart rate
Bpm	Beats per minute
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
BMI	Body mass index
SpO_2	Oxygen saturation percentages
ANOVA	Analysis of variance
mv	Millivolt
ms	Millisecond
QTc	Corrected QT interval
Tpe	Tpeak-Tend interval
TSNAs	Tobacco-specific nitrosamines
VOCs	Volatile organic compounds

Acknowledgements

Not applicable.

Authors' contributions

AH, RH and HA proposed the idea and designed the study. HA collected the data. AS collected the clinical data and recorded and analyzed the electrocardiographic traces. HA has performed the statistical analysis and wrote the initial draft. AH, RH, ShA, and AS shared in revising the final manuscript. All authors have approved the manuscript.

Funding
This study was self-funded.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the research ethics committee of the Faculty of Medicine, Suez Canal University. A written informed consent had been taken from all participants.

Consent for publication
This study does not include the publishing of personal data.

Competing interests
The authors declare that they have no competing interests.

Received: 1 October 2023 Accepted: 1 January 2024
Published online: 22 January 2024

References

1. Perez-Warnisher MT, de Miguel MPC, Seijo LM (2019) Tobacco use worldwide: legislative efforts to curb consumption. Ann Glob Health 84(4):571–579
2. Kondo T, Nakano Y, Adachi S, Murohara T (2019) Effects of tobacco smoking on cardiovascular disease. Circ J 83(10):1980–1985
3. Jirjees F, Dallal Bashi YH, Kharaba Z, Ahmadi K, Barakat M, AlObaidi H (2023) Public awareness, prevalence, and regulations for the sale of electronic cigarettes in Arab countries: a narrative review. Tob Induc Dis 21:143
4. Marques P, Piqueras L, Sanz M-J (2021) An updated overview of e-cigarette impact on human health. Respir Res 22(1):151
5. Sapru S, Vardhan M, Li Q, Guo Y, Li X, Saxena D (2020) E-cigarettes use in the United States: reasons for use, perceptions, and effects on health. BMC Public Health 20(1):1518
6. Gomajee R, El-Khoury F, Goldberg M, Zins M, Lemogne C, Wiernik E et al (2019) Association between electronic cigarette use and smoking reduction in France. JAMA Intern Med 179(9):1193–1200
7. Benowitz NL, St.Helen G, Nardone N, Addo N, Zhang J (Jim), Harvanko AM et al (2020) Twenty-four-hour cardiovascular effects of electronic cigarettes compared with cigarette smoking in dual users. J Am Heart Assoc 9(23):e017317
8. Espinoza-Derout J, Shao XM, Lao CJ, Hasan KM, Rivera JC, Jordan MC et al (2022) Electronic cigarette use and the risk of cardiovascular diseases. Front Cardiovasc Med 9:879726
9. Shi H, Fan X, Horton A, Haller ST, Kennedy DJ, Schiefer IT et al (2019) The effect of electronic-cigarette vaping on cardiac function and angiogenesis in mice. Sci Rep 9:4085
10 MacDonald A, Middlekauff HR (2019) Electronic cigarettes and cardiovascular health: what do we know so far? Vasc Health Risk Manag 15:159–74
11. Sattar Y, Chhabra L (2023) Electrocardiogram. In: StatPearls. Treasure Island: StatPearls Publishing; 2023. Available from: http://www.ncbi.nlm.nih.gov/books/NBK549803/. Cited at November, 2023
12. Harskamp RE (2019) Electrocardiographic screening in primary care for cardiovascular disease risk and atrial fibrillation. Prim Health Care Res Dev 20:e101
13. Bilge S, Tezel O, Acar YA, Cuce F, Karadas O, Tasar M (2020) Investigation of the value of T peak to tend and QTc intervals as electrocardiographic arrhythmia susceptibility markers in acute ischemic stroke. Arch Neuropsychiatry 57(3):171–176
14. Takeguchi M, Kusumoto S, Sekiguchi K, Suenobu S, Ihara K (2023) Predicting long-term ventricular arrhythmia risk in children with acute lymphoblastic leukemia using normal values of ventricular repolarization markers established from Japanese cohort study. J Clin Med 12(14):4723
15. Braun CC, Zink MD, Gozdowsky S, Hoffmann JM, Hochhausen N, Röhl AB et al (2023) A longer tpeak-tend interval is associated with a higher risk of death: a meta-analysis. J Clin Med 12(3):992
16. Lee WH, Ong SG, Zhou Y, Tian L, Bae HR, Baker N et al (2019) Modeling cardiovascular risks of E-cigarettes with human induced pluripotent stem cell-derived endothelial cells. J Am Coll Cardiol 73(21):2722–2737
17. Shmulewitz D, Greenstein E, Stohl M, Fink DS, Roncone S, Walsh C et al (2022) Validity of the DSM-5 tobacco use disorder diagnostics in adults with problematic substance use. Drug Alcohol Depend 234:109411–109430
18. Grant BF, Shmulewitz D, Compton WM (2020) Nicotine use and DSM-IV nicotine dependence in the United States, 2001–2002 and 2012–2013. AJP 177(11):1082–1090
19. Jessri M, Sultan AS, Magdy E, Hynes N, Sultan S (2020) Nicotine e-vaping and cardiovascular consequences: a case series and literature review. Eur Heart J - Case Rep 4(6):1–7
20. Arastoo S, Haptonstall KP, Choroomi Y, Moheimani R, Nguyen K, Tran E et al (2020) Acute and chronic sympathomimetic effects of e-cigarette and tobacco cigarette smoking: role of nicotine and non-nicotine constituents. Am J Physiol Heart Circ Physiol 319(2):262–270
21. Shahandeh N, Chowdhary H, Middlekauff HR (2021) Vaping and cardiac disease. Heart 107(19):1530–1535
22. Bayramoğlu A, Taşolar H, Bektaş O, Kaya A, Günaydın ZY (2019) Association between fragmented QRS complexes and left ventricular dysfunction in healthy smokers. Echocardiography 36(2):292–296
23. Lan R, Bulsara MK, Pant PD, Wallace HJ (2021) Relationship between cigarette smoking and blood pressure in adults in Nepal: a population-based cross-sectional study. PLoS Global Public Health 1(11):e0000045
24. McClelland ML, Sesoko CS, MacDonald DA, Davis LM (2020) (2020) Effects on vital signs after twenty minutes of vaping compared to people exposed to second-hand vapor. Adv Respir Med 88(6):504–514
25 Harikrishnan K, Sridhar C, Raja K, Narayanan N, B E (2019) Evaluation of the cardiovascular risk by early ECG changes in smokers – a cross sectional study. Asian J Med Res 8(4):ME07-ME10
26. Özdemir L, Sökmen E (2020) Effect of habitual cigarette smoking on the index of cardiac electrophysiological balance in apparently healthy individuals. J Electrocardiol 10:59
27 Shukla PK, Sharma R, Meshram R, Das A, Bastia BK (2021) A cross-sectional study to assess the cardiovascular risk of chronic cannabis smoking through electrocardiograph (ECG): ECG changes among cannabis, tobacco & non-smokers. Emerg Trends Drugs Addict Health 1:100026
28. Demir V, Hidayet S, Turan Y, Ede H (2020) Acute effects of electronic cigarette smoking on ventricular repolarization in adults. Afr Health Sci 20(4):1793–1799
29. Tokgozoglu L, Hekimsoy V, Costabile G, Calabrese I, Riccardi G (2022) Diet, lifestyle, smoking. Handb Exp Pharmacol 270:3–24
30. Shomanova Z, Ohnewein B, Schernthaner C, Höfer K, Pogoda CA, Frommeyer G, Wernly B, Brandt MC, Dieplinger A, Reinecke H, Hoppe UC, Strohmer B, Pistulli R, Motloch LJ (2020) Classic and novel biomarkers as potential predictors of ventricular arrhythmias and sudden cardiac death. J Clin Med 9(2):578

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.