



Regional French evolution of tobacco and e-cigarette experimentation and use among adolescents aged 15–16 years: A cross-sectional observational study conducted in the Loire department from 2018 to 2020

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ABSTRACT

Background: We assessed/compared the evolution of tobacco and e-cigarette experimentation and use among French adolescents of the Loire department aged 15–16 years.

Methods: A descriptive, cross-sectional/observational study conducted in 2018–2020 among 7,950 Year 11 pupils attending 27 public secondary schools of the Loire department, France.

Results: From 2018 to 2020, 66.18% of adolescents were “non-vapers and non-smokers”, 19.76% were “vapers and smokers”, 7.90% were “non-vapers and smokers” and 6.15% were “vapers and non-smokers”. E-cigarette experimentation was more prevalent than tobacco experimentation (44.92% vs 41.67%), and daily vaping was less prevalent than daily smoking (5.40% vs 10.24%). More boys than girls were daily vapers or daily smokers. A decrease was observed in tobacco experimentation (from 41.22% in 2018 to 39.73% in 2020) and e-cigarette experimentation (from 50.28% in 2018 to 41.25% in 2020). Current vaping remained stable, with an increase in daily vaping. French adolescent vapers frequently use e-liquids with little or no nicotine or with fruit or sweet flavours.

Conclusions: Adolescents used e-cigarettes mainly for experimental and/or recreational purposes, with no intention of progression to daily smoking. Although the design of this study is not longitudinal and caution must be exercised, from our cross-sectional observational study data, it appears that the proportion of “non-vapers and non-smokers” tended to increase. “Smokers” tended to progress to the dual use of vaping and smoked tobacco, with the likely intention to reduce or quit smoking.

1. Introduction

1.1. Scientific controversies on e-cigarettes perceptions

A major scientific controversy is currently ongoing based on contrasting perceptions of e-cigarettes. On one side of the debate are those who consider that vaping helps smokers reduce or quit smoking. Some authors note that e-cigarettes are perceived as a smoking cessation tool (Hanafin and Clancy, 2020), with smokers themselves highlighting their

therapeutic potential (Berlin, 2015; Hardie and Green, 2022; Kinouani et al., 2020; Notley et al., 2021). Three Cochrane reviews find that nicotine e-cigarettes are more effective than nicotine substitutes in helping young adult smokers wean themselves off smoking (Grabovac et al., 2020; Hartmann-Boyce et al., 2021; McRobbie et al., 2014). The data from these studies (McRobbie et al., 2014) also highlights that a large proportion of smokers who switch to vaping continue to vape, failing to achieve the primary goal of quitting. The Cochrane review also features data on the growing number of dual-users as a result of

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experimentation or use of electronic cigarettes as a cessation tool. In the UK, the 2021 Public Health England report (McNeill et al., 2021) concludes that e-cigarettes are an effective aid to smoking cessation and reduction, while Levy et al. (Levy et al., 2020) suggest that the observed reduction in smoking prevalence in the adult population is explained by the increased use of nicotine e-cigarettes. In France, Legleye et al. (Legleye et al., 2020) report a 42% reduction in the risk of becoming a daily smoker in adolescents aged 17–18.5 years who experimented with e-cigarettes first: the proportion of subsequent tobacco experimenters decreased continuously with age at exposure from 95% at age 11 to 25.3% at 17 years, and within the French population, Chyderiotis et al. (Chyderiotis et al., 2020) confirm the absence of an increased risk of progression from vaping to daily smoking among adolescents aged 17 years.

On the other side of the debate are those who view vaping as a gateway to smoking. A detailed report of the National Academies of Sciences, Engineering and Medicine (Daynard, 2018); National Academies of Sciences, 2018; Stratton et al., 2018) describes e-cigarettes as a “gateway” object and concludes that they are associated with the risk of progression to smoking, especially when they contain nicotine. Likewise, a meta-analysis of 30 longitudinal studies from 22 different cohorts states that e-cigarette use can be considered a predictor of subsequent smoking (Adermark et al., 2021). Several other studies (Martinelli et al., 2021; Soneji et al., 2017; Zhong et al., 2016) highlight an association between e-cigarette use and subsequent smoking initiation among adolescents and young adults. More generally, Brown et al. (Brown et al., 2020) and Kinnunen et al. (Kinnunen et al., 2019) recommend caution over nicotine e-cigarettes, arguing that nicotine exposure can cause dependence and, consequently, the progression to smoking among young vapers.

The contrasting perceptions of e-cigarettes have raised concerns among public health agencies about the uncertain impact of vaping in the general population, and especially in adolescents (Chyderiotis et al., 2019). For public health authorities to make fully informed decisions, it is crucial to better understand both the relationship between smoking and vaping in adolescence and the motivations of adolescents for tobacco and e-cigarette experimentation and use. As previously discussed, in general adolescent data are sorely lacking. Thus, we chose to work on 15–16-year-olds, although it will be of course essential to expand into any adolescent population. Thus, with a view to reinforcing French observational systems, we conducted a cross-sectional study to complement national data with regional data on smoking and vaping behaviour in the specific population of adolescents aged 15–16 years. Our main objective was to assess and compare the evolution of tobacco and e-cigarette experimentation and use among thousands of Year 11 pupils attending public secondary school in the Loire department. The point was to closely examine the regional evolution of smoking and vaping behaviour at the specific age of 15–16 years. Our secondary objective was to identify the motivations of some French adolescents from the Loire department for vaping and smoking and to describe the characteristics of their preferred e-liquids (nicotine content, flavour). Detailed information is available in the [supplementary material](#) to this article regarding the most recent French data on the prevalence of e-cigarette experimentation and smoking (see [section 1 of Appendix A](#)).

2. Materials and methods

A descriptive, cross-sectional, observational study was conducted from 2018 to 2020 in a population of 7,950 French adolescents aged 15–16 years and attending Year 11 in 27 public secondary schools of the Loire department, France. This study was approved by the ethics committee of Saint-Etienne University Hospital (CHU) and referenced under the number IRBN372018/CHUSTE. The study obtained written informed consent from the French ethics committee on behalf of all the research participants. It has received approval from the French Data Protection Authority (Commission Nationale de l’informatique et des

Libertés) (CNIL). It was carried out in partnership between the Departmental Services of National Education of the Loire, Saint-Etienne University Hospital and the Ecole Nationale Supérieure des Mines de Saint-Etienne.

The 27 high schools eligible to participate in the surveys were included in the sample on the basis of voluntary participation. To recruit participants, an information note was sent through the management of each high school to students and their parents before the questionnaire was administered. The note specified that participation in the survey was voluntary, and that to complete the questionnaire the students had to be present in a room reserved by the school management. Data was collected using self-administered questionnaires drawn up by a multi-disciplinary team composed of a tobacco specialist, scientist specialized in adolescence, a researcher in public health and educational sciences as well as aerosol experts and toxicologists specialized in smoking and vaping. Adolescents were asked to answer a number of questions on their experimentation and use of tobacco and e-cigarettes allowing to determine their vaping or smoking status as previously described in Denis-Vatant et al. (Denis-Vatant et al., 2019) study. The status of “smoker” or “vaper” corresponds to adolescents who report, respectively, smoking tobacco or vaping electronic cigarettes, daily (every day) or occasionally (only on weekends, during festive events). The status of “non-smoker” or “non-vaper” corresponds to adolescents who declare at the time of the study, respectively, that they do not smoke tobacco or vape electronic cigarettes. Preliminary reliability and validity tests were conducted with some of the adolescents during the design phase of the questionnaires to ensure proper understanding of the questions.

The analysis sought to determine whether the prevalence of vaping and smoking increased, decreased or remained stable from 2018 to 2020. The motivations of adolescents for vaping and smoking and their e-liquid preferences were also analyzed, as was the evolution of these motivations and preferences over time. Questionnaires were processed anonymously using Excel® software. Statistical analyses were carried out using IBM SPSS Statistics 21® software. Percentages were compared in univariate analysis using the Chi-square test. Univariate analysis was carried out on all the variables. The statistical tests used are: χ^2 test, Fisher’s exact test and Wilcoxon test. Using SPSS statistical software, the data collected was weighted, which made it possible to correct the under- and over-representation of the sample of study participants.

Additional information is available in the [supplementary material](#) to this article regarding the protocol for administering the questionnaire and the data collection (see [section 2 of Appendix A](#)).

3. Results

A total of 7,950 adolescents aged 15–16 years were included in the study, namely 1,435 (18%) in 2018, 4,937 (62%) in 2019 and 1,578 (20%) in 2020. Overall, 4,112 (51.70%) girls and 3,838 (48.30%) boys responded to the questionnaire. While the sex ratio was similar in 2018 and 2019, there was a significant female predominance in 2020 ([Table 1](#)). Thus, the fact that the same sex ratio was observed in 2018 and 2019 is reassuring that there is no bias despite the difference in sample size for these two years. In contrast, the different sex ratio in the population included in 2020 during the COVID-19 pandemic could

Table 1
Evolution of cross-sectional sample according to sex among French adolescents of the Loire department aged 15–16 years from 2018 to 2020.

Years	Number of adolescents included	Sex				
		%	Girls	%	Boys	%
2018	1435	18%	716	49.18%	719	50.82%
2019	4937	62%	2491	50.46%	2446	49.54%
2020	1578	20%	905	57.35%	673	42.65%
Total	7950	100%	4,112	51.70%	3,838	48.30%

induce a potential bias (excepted if we compare use by sex) even in terms of inclusion the sample size is globally very similar to that in 2018. However, overall, the sex ratio for the total population included over the three years is very close to that observed in 2018 and 2019, despite the difference observed in 2020, which does not seem to induce a particular bias with respect to the overall population ($p < 0.001$).

3.1. Evolution of tobacco experimentation and use

Overall, 41.67% ($n = 3,241$) of adolescents reported having experimented with at least one tobacco product. The prevalence of current smoking was 27.50% ($n = 2,170$) (for 2018/2019/2020, $p = 0.442$), with more adolescents reporting occasional smoking (17.27%, $n = 1,351$) than daily smoking (10.24%, $n = 805$). The prevalence of use and experimentation of smoking for the 7,950 adolescents included in the study between 2018 and 2020 is shown in the [Table 2](#).

As the analysis by year indicates, the prevalence of tobacco experimentation remained broadly stable between 2018 (39.7%) and 2019 (42.4%) and then decreased in 2020 (41.2%). There was also a slight decrease in the prevalence of daily smoking (from 10.86% in 2018 to 9.44% in 2020; $p = 0,3$) and that of occasional smoking (from 17.11% in 2018 to 16.86% in 2020; $p = 0,48$). The percentage of non-smokers remained stable between 2018 (72.02%) and 2019 (72.23%) and then increased by one point in 2020 (73.70%; $p = 0,6$) ([Fig. 1](#)).

3.2. Evolution of e-cigarette experimentation and use

Overall, 44.9% ($n = 3,531$) of adolescents reported having experimented with e-cigarettes. Moreover, 25.9% ($n = 2,027$) reported being current vapers. The prevalence of occasional vaping was 20.44% ($n = 1,592$) and that of daily vaping was 5.40% ($n = 385$). The prevalence of use and experimentation of vaping products for the 7,950 adolescents included in the study between 2018 and 2020 is shown in the [Table 2](#). The analysis by year shows an important decrease in the prevalence of e-cigarette experimentation: from 50.28% in 2018 to only 44.60% in 2019 and 41.25% in 2020. The prevalence of occasional vaping remained stable between 2018 (19.96%) and 2020 (19.90%), despite a one-point increase in 2019 (20.74%; $p = 0,459$). However, the prevalence of daily vaping increased significantly from 3.50% in 2018 to 5.13% in 2020 ($p = 0,045$) ([Fig. 2](#)).

3.3. Evolution of vaping and smoking status

Overall, 66.18% ($n = 5,221$) of adolescents were “non-vapers and non-smokers”, 19.76% ($n = 1,506$) were “vapers and smokers”, 7.90% ($n = 673$) were “non-vapers and smokers” and 6.15% ($n = 483$) were “vapers and non-smokers”. The analysis of vaping and smoking status by year shows a significant increase in the prevalence of “non-vapers and non-smokers”, from 64.85% ($n = 887$) in 2018 to 66.03% ($n = 3260$) in 2019 and 67.81% ($n = 1,070$) in 2020 ($p = 0,003$). The prevalence of “vapers and smokers” in 2020 (19.14%) was 1.42 points higher than in

Table 2

Prevalence (of use and experimentation) of tobacco and vaping products for the 7,950 French adolescents of the Loire department included in the study between 2018 and 2020.

		Smoking	Vaping products
Prevalence of use ($n = 7,950$)	Daily use	10.24%	5.40%
	Occasional use	17.27%	20.44%
	Non-user	72.49%	74.16%
Prevalence of experimentation ($n = 7,950$)	Experimenter	41.67%	44.92%
	Non-experimenter	58.33%	55.08%

2019 (20.56%) and 1.54 points lower than in 2018 (17.60%), but almost identical to the average prevalence of “vapers and smokers” for the entire study period (19.76% vs 19.14%). The prevalence of “non-vapers and smokers” fell significantly from 11.25% ($n = 154$) in 2018 to only 7.21% ($n = 356$) in 2019 and 7.16% ($n = 113$) in 2020 ($p = 0,297$). As for the prevalence of “vapers and non-smokers”, it remained stable between 2018 (6.30%, $n = 86$) and 2019 (6.20%, $n = 306$) and then fell slightly in 2020 (5.89%, $n = 93$) ($p = 0,444$). In contrast, the prevalence of “vapers and smokers” increased significantly from 17.60% ($n = 241$) in 2018 to 20.56% ($n = 1,015$) in 2019 and fell to 19.14% ($n = 302$) in 2020 ($p = 0,001$) ([Fig. 3](#)).

Additional results are available in the [supplementary material](#) to this article regarding, the evolution of tobacco experimentation and use by sex, the evolution of e-cigarette experimentation and use by sex, what do French Adolescents like in terms of Motivations for vaping and smoking, and finally the nicotine content and flavour of e-liquids used and preferred types of vaping products (see [section 3 of Appendix A](#)).

4. Discussion

In France, a sharp decline in smoking prevalence has been observed among adults ([Pasquereau et al., 2021](#)) and adolescents aged 17 years since 2014. In this context, our study aimed to assess and compare the evolution of smoking and vaping behaviour among French adolescents aged 15–16 years. Specifically, we sought to determine whether the prevalence of tobacco and e-cigarette experimentation and use increased, decreased or remained stable among Year 11 pupils attending public secondary school in the Loire department between 2018 and 2020.

On the one hand, we can compare the prevalence of tobacco use and experimentation obtained in our study to some results described in the literature. In our sample of adolescents aged 15–16 years, the average prevalence of tobacco experimentation over the study period was 41.67%. This figure is almost identical to the European average (41%) and slightly lower than the French average (45%) reported in the 2019 *ESPAD* report for adolescents of the same age (15–16 years) ([Mokinaro et al., 2020](#)). The average prevalence of current smoking was 27.51%, which is nearly identical to the average prevalence reported by the OFDT (27.58%) for all French departments for the year 2021 ([Vuolo et al., 2021](#)) but lower than the European (30%) and French (34%) averages reported in the 2019 *ESPAD* report ([Mokinaro et al., 2020](#)). The average prevalence of daily smoking (10.24%) was very close to the European average (10.0%) and slightly lower than the French average (12%), while that of occasional smoking (17.27%) was lower than both the European (20%) and French (22%) averages ([Mokinaro et al., 2020](#)). Between 2018 and 2020, a continuous decline was observed in tobacco experimentation in our sample. A similar downwards trend was observed in the study by Chyderiotis et al. ([Chyderiotis et al., 2020](#)) and in the 2017 *ESCAPAD* survey ([Le Nézet et al., 2018](#)) for adolescents aged 17 years. Likewise, the prevalence of daily smoking decreased in our sample, which is perfectly consistent with the results of the 2015 and 2019 *ESPAD* reports for French adolescents aged 15–16 years ([Kraus and Nociar, 2016; Mokinaro et al., 2020](#)). This decline is also in line with the findings of the 2017 ([Pasquereau et al., 2018](#)) and 2018 *Baromètre Santé* surveys ([Andler et al., 2019](#)) for the adult population and those of the 2017 *ESCAPAD* survey ([Spilka et al., 2018](#)). In the US, the study by Jarvis et al. ([Jarvis et al., 2020](#)) observed a similar decrease (20.4%) in smoking prevalence among adolescents (from 28.5% in 1999 to 8.1% in 2018), a trend that was associated with the increased market availability of e-cigarettes in the study by Sokol et al. ([Sokol and Feldman, 2021](#)).

On the other hand, we can compare the prevalence of vaping use and experimentation obtained in our study to some results described in the literature. The average prevalence of e-cigarette experimentation over the study period was 44.92%. This figure is higher than the European average (40%) and almost identical to the French average (46%) reported in the 2019 *ESPAD* report for adolescents of the same age

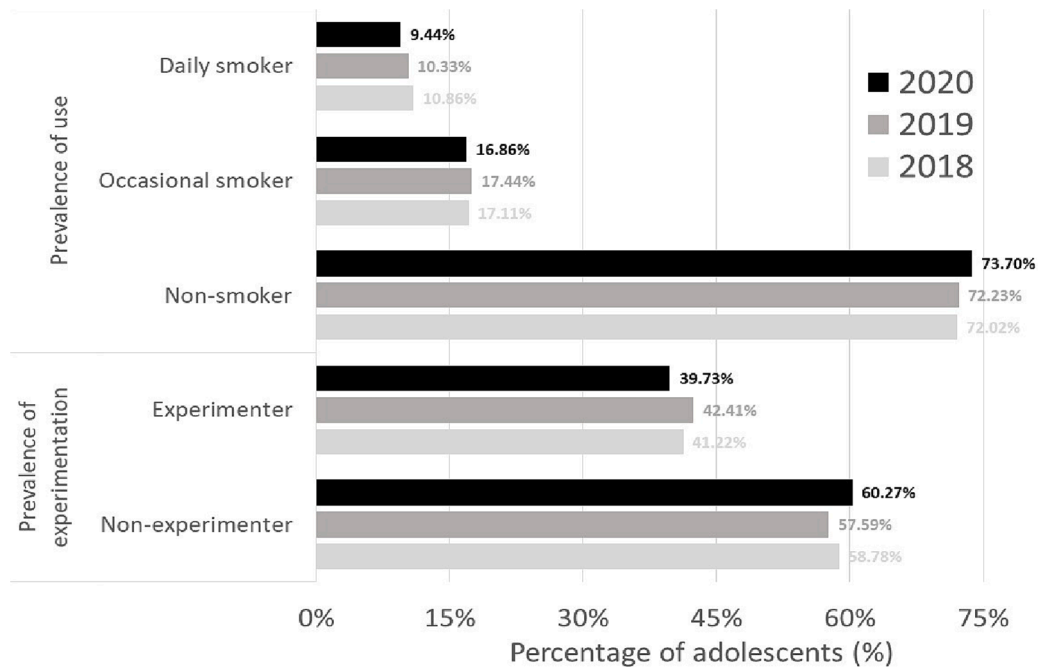


Fig. 1. Evolution of tobacco experimentation and use among French adolescents of the Loire department aged 15–16 years from 2018 to 2020.

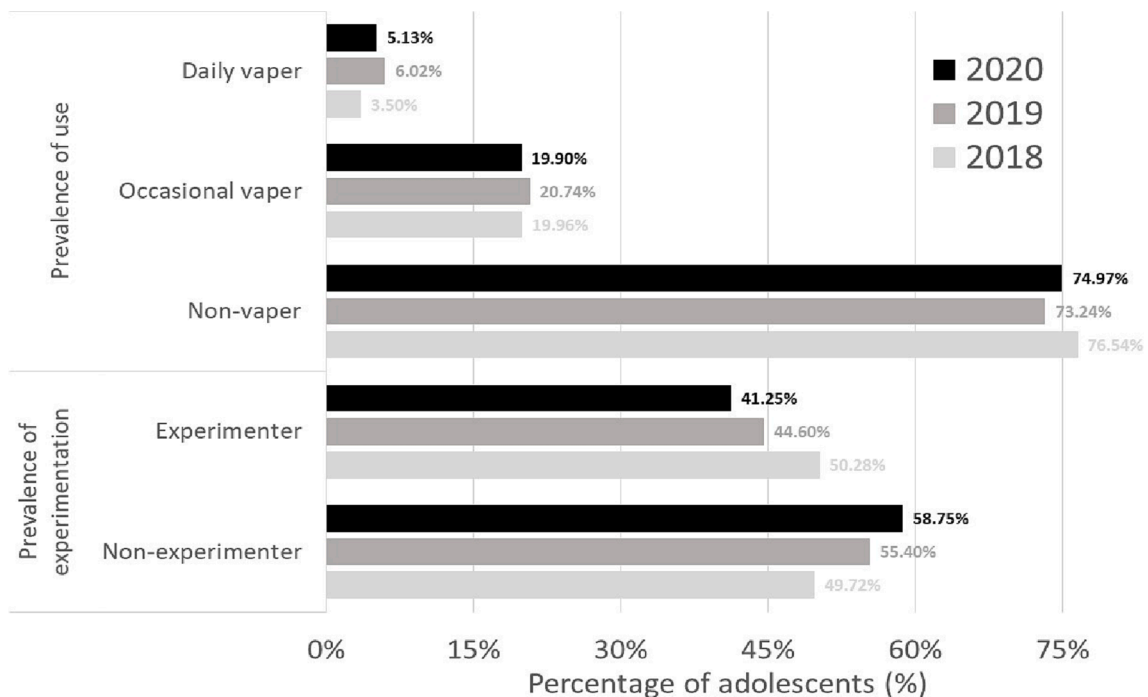


Fig. 2. Evolution of e-cigarette experimentation and use among French adolescents of the Loire department aged 15–16 years from 2018 to 2020.

(Mokinaro et al., 2020). By contrast, the average prevalence of daily vaping was low at 5.40%. The prevalence of e-cigarette experimentation in our sample decreased from 50.28% to 41.25% between 2018 and 2020. However, if we compare the prevalence of e-cigarette experimentation for the year 2020 with that reported in the 2015 ESPAD report (35.1%) (Kraus and Nociar, 2016), we observe a considerable increase in this indicator over a period of 5 years. Conversely, the prevalence reported in the 2018 EnCLASS report (52.1%) (Spilka et al., 2019) suggests a decrease in this indicator between 2018 and 2020. It should be noted that in the study by Hammond et al. (Hammond et al.,

2020), the prevalence of e-cigarette experimentation increased from 29.3% in 2017 to 40.6% in 2019 among adolescents aged 16–19 years. Over the same period, the study by Jarvis et al. (Jarvis et al., 2020) observed a statistically significant increase of 15.8% (from 11.7% to 27.5%) in the prevalence of past-30-day e-cigarette use among high school students in the US. In our sample of French adolescents of the Loire department, there was a moderate increase in daily vaping (from 3.50% in 2018 to 5.13% in 2020), but this finding needs to be confirmed in future studies.

Over the study period, the prevalence of current smoking was higher

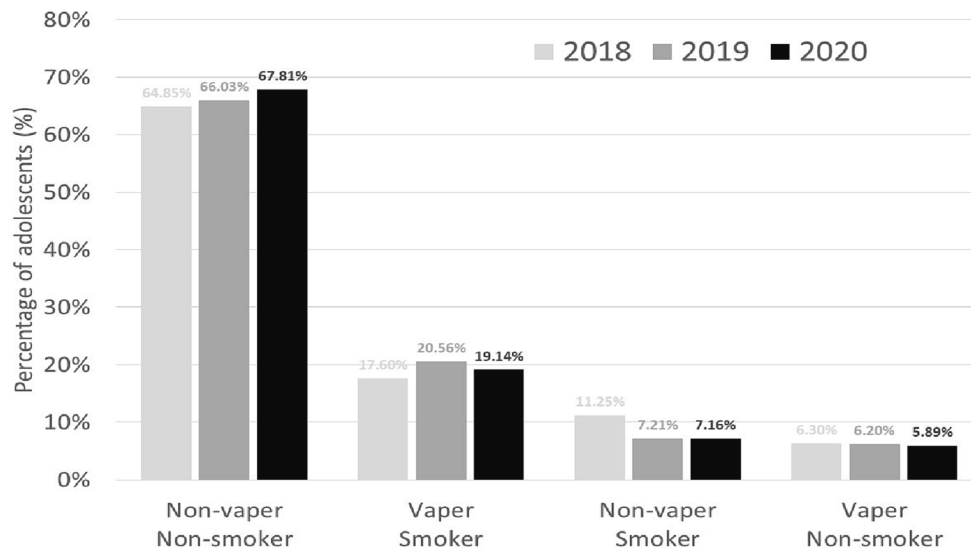


Fig. 3. Evolution of vaping and smoking behaviour among French adolescents of the Loire department aged 15–16 years from 2018 to 2020.

in boys than in girls, as was that of current vaping. These findings are in line with published data showing a male predominance in the prevalence of smoking and vaping in adolescents, young adults and the general population in France and beyond (Denis-Vatant et al., 2019; Spilka et al., 2018).

In our study, approximately one in five (19.76%) adolescents were dual users of vaping and smoked tobacco. The exclusive use of either type of products was less frequent, as only 7.90% of adolescents were ‘non-vapers and smokers’ and 6.15% were ‘vapers and non-smokers.’ These results are consistent with other French studies conducted among adolescents aged 17 years (Chyderiotis et al., 2019) and with studies from the UK (Aladeokin and Haighton, 2019). Between 2018 and 2020, the proportion of “non-vapers and non-smokers” increased from 64.85% to 67.81%, while that of “vapers and non-smokers” remained stable with a slight decrease from 6.30% to 5.89%. Our analysis could not provide reliable results on the proportion of “non-vapers and smokers” who became “vapers and non-smokers” or “non-vapers and non-smokers”. However, we did find that 2–3% of “non-vapers and smokers” seems to progress to the dual use of vaping and smoked tobacco. This progression may be explained by the fact that exclusive smokers initiate vaping with the intent to reduce or quit smoking in the future. In this regard, the study by 2021 Eurobarometer survey (Eurobarometer, 2021) found dual users to be more likely to attempt to quit smoking than exclusive smokers. Yet, the progression from exclusive tobacco use to dual use could also be explained by a loss of interest in smoking and a concomitant desire to adopt exclusive vaping. The motivations for this progression have so far been studied by means of quantitative approaches (Khouja et al., 2021; McCabe et al., 2019) and should be clarified in future studies using qualitative methods.

Our most relevant finding for public health was the temporal coincidence between an increase in the prevalence of daily vaping and a decrease in that of daily smoking. This finding may be explained by the fact that adolescents who first experiment with e-cigarettes are more likely not to initiate smoking or to delay their entry into smoking. Thus, the study by Chyderiotis et al. (Chyderiotis et al., 2019) found that French adolescents aged 17 years who initially experiment with e-cigarettes have a very low risk of becoming daily smokers. Likewise, in the study by Friedman et al. (Friedman and Xu, 2020), adolescent dual users who had experimented with e-cigarettes first were less likely to become daily smokers than those who had experimented with tobacco first. In the study by Legleye et al. (Legleye et al., 2020), experimenting with e-cigarettes before tobacco cigarettes was associated with a 42% reduction in the risk of daily smoking among youth aged 18 to 21 years. Kalkhoran

et al. (Kalkhoran et al., 2020) found early e-cigarette use to be associated with higher odds of prolonged smoking abstinence, suggesting that e-cigarettes play a role in delaying smoking initiation (Etter, 2018). Lastly, the study by Coleman et al. (Coleman et al., 2019), conducted in the same sample of US adults, noted that dual users who had initially experimented with e-cigarettes were more likely to quit smoking than those who had initially experimented with tobacco. Future studies are needed to determine the association between vaping initiation and smoking prevalence at the specific age of 15–16 years.

Additional discussion points are available in the [supplementary material](#) for this article regarding the motivations for e-cigarette and tobacco experimentation and use among French adolescents of the Loire department aged 15–16 years, and the study limitations (see [section 4 of Appendix A](#)).

5. Conclusions

Our study shows that e-cigarette experimentation is significantly more prevalent than tobacco experimentation among French adolescents of the Loire department aged 15–16 years. Between 2018 and 2020 a clear increase is observed in the prevalence of daily vaping. Their motivations for experimenting with e-cigarettes seem to be mainly associated with recreational leisure, much less so with the desire to reduce or quit smoking. No increase was observed in the progression from vaping to smoking in our sample. French adolescent vapers of the Loire department frequently use e-liquids with little or no nicotine or with fruit or sweet flavours. Besides, some “non-vapers and smokers” seems to switch to dual use, maybe with the likely intention to reduce or quit smoking. E-liquids without or with low nicotine content and flavours with fruity and sweet tastes are frequently used in electronic cigarettes, which would explain, in part, the lack of increased risk of switching from vaping to smoking. Given the increase in the proportion of “non-vapers and non-smokers” and the stabilization of e-cigarette use, the health situation of French adolescents of the Loire department aged 15–16 years can be said to have globally improved between 2018 and 2020.

Authors contributions

A. Wamba drafted and reviewed the manuscript; J. Pourchez co-drafted the manuscript, coordinated the project; M. Nekaa co-coordinated the project and conducted the statistical analyses; J. Masson co-coordinated the project and reviewed the literature; L. Leclerc

read and reviewed the manuscript; C. Denis-Vatant read and reviewed the manuscript; All authors contributed to substantial editing of the manuscript and approved the final submitted version. All authors agreed to be personally accountable for their contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which they were not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Institutional Review Board Statement

The study was approved by the ethics committee of Saint-Etienne University Hospital (CHU) and referenced under the number IRBN372018/CHUSTE. The methods were carried out in accordance with the relevant guidelines and regulations set out in the Declaration of Helsinki.

Informed Consent Statement

The study obtained written informed consent from the French ethics committee on behalf of all the research participants. It has received approval from the French Data Protection Authority (Commission Nationale de l'informatique et des Libertés) (CNIL).

Data Availability Statement

The datasets accessed in this research are owned and administered by the UMR INSERM U 1059 Sainbiose, "Écoles des Mines de Saint-Etienne" (Université Jean Monnet), Saint-Etienne, France. Availability is at the discretion of Écoles des Mines de Saint-Etienne (Université Jean Monnet), Saint-Étienne, France. The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

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.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2023.102278>.

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