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Exclusive and dual use of electronic cigarettes among European youth in 32 countries with different regulatory landscapes

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ABSTRACT

Background The Tobacco Products Directive (2014/40/EU) partially harmonised the regulation of electronic cigarettes (e-cigarettes) in Europe, but individual countries maintain jurisdiction over bans on use in public places, domestic advertising, taxation and flavour regulations. Their association with youth e-cigarette use has not been examined.

Methods We used the cross-sectional 2019 European School Survey Project on Alcohol and Other Drugs data from 32 countries with 98 758 students aged 15–16 years and the 2020 WHO's assessment of the e-cigarette regulations. Multilevel logistic regression models on ever (vs never) and current (vs non-current) exclusive e-cigarette use, exclusive cigarette use and dual use by e-cigarette regulations' composite score were adjusted for age, gender, parental education, perceived family's financial well-being, perceived difficulty of obtaining cigarettes, country income level and general progress in tobacco control.

Results Of the respondents, 13.3% had ever used cigarettes, 10.6% e-cigarettes and 27.3% both; 13.0% currently used cigarettes, 6.0% e-cigarettes and 6.4% both. Higher composite country score in the e-cigarette regulations was associated with lower current exclusive e-cigarette use (OR=0.78; 95% CI 0.65 to 0.94) and current dual use (OR=0.80; 95% CI 0.67 to 0.95). Youth perceiving more difficulties in obtaining cigarettes were less likely to use cigarettes, e-cigarettes and both ever and currently (OR from 0.80 (95% CI 0.76 to 0.85) to 0.94 (95% CI 0.92 to 0.96)).

Conclusions More comprehensive e-cigarette regulations and enforcement of age-of-sale laws may be protective of e-cigarette and dual use among adolescents.

INTRODUCTION

In the last decade, the global progress in tobacco control has been challenged by the emergence of non-combustible nicotine products, including electronic cigarettes (e-cigarettes)—the most common form of electronic nicotine/non-nicotine delivery systems. The governing body of the WHO Framework Convention on Tobacco Control (FCTC) has recommended several regulatory options for these products, but no requirements have been agreed on.¹ In Europe, the Tobacco Products Directive (2014/40/EU) has partially regulated e-cigarettes and e-liquids, but substantial regulatory areas remain under national jurisdictions. These include taxation, age limits, domestic advertising,

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Countries have different e-cigarette regulations and their relation to youth e-cigarette use is not known.

WHAT THIS STUDY ADDS

⇒ Current use of e-cigarettes exclusively and in combination with cigarettes is less likely in countries with more comprehensive e-cigarette regulations.
⇒ Perceived difficulty in obtaining cigarettes appears to be protective for e-cigarette use.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Adopting comprehensive e-cigarette regulations that address protection from exposure, advertising, taxation and flavours may support prevention of use among youth.

promotion, and sponsorship, e-cigarette use in public places and regulation of flavours. Seven out of 53 countries in the WHO European region have prohibited e-cigarette use completely in public places and implemented complete advertising bans, and 20 countries have imposed some form of excise tax on e-liquids.^{1 2} Most countries have adopted an age limit of 18 for sales to minors, but only six countries in the region have regulated the use of flavours in e-liquids.^{1 2}

By ratifying the WHO FCTC, countries have committed to protect the present and future generations from tobacco use and nicotine addiction. Variations in the existence and coverage of the national e-cigarette regulations raise concerns on the ability of countries to prevent e-cigarette use among adolescents. A recent meta-analysis representing 69 countries/territories found a 17% estimated prevalence of ever and 8% of current (ie, past 30 days) e-cigarette use among youth under the age of 20, with the highest prevalence in high-income countries.³ In Europe, among 15–16 year-olds from 35 countries, considerably higher figures were reported with an average of 40% ever (lifetime) users and 14% current users.⁴ The highest prevalence was 65% for ever use (Lithuania) and 41% for current use (Monaco). Adolescents who use e-cigarettes are more than twice likely to later use conventional cigarettes,^{5 6} and there is a pattern of dual or multiple tobacco and nicotine product use among youth.^{7–9} Further, lack of knowledge



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of nicotine and other e-liquid contents among youth,^{4 7} availability of youth-appealing flavours and their use in the initiation phase,^{1 4 10 11} frequent promotion online and in social media¹² and easy access to products through peers, online shops and weak enforcement of age-of-sale laws¹³ create challenges for prevention. In youth, nicotine addiction can develop from more infrequent use and lower levels of exposure than among adults.¹⁴ Evidence has emerged on youth reporting dependence from exclusive e-cigarette use, with symptoms differing between device types.¹⁵

While there were notable increases in the use of e-cigarettes among youth in several countries,^{16 17} some countries such as Finland and USA reported reductions in connection with strengthening regulations.^{9 17–19} However, cross-country associations between national e-cigarette regulations and e-cigarette use among youth are unknown. Two recent studies have examined youth e-cigarette use in the context of implementation of tobacco control policies, but not e-cigarette-specific regulations. Chan *et al*²⁰ linked the WHO MPOWER implementation and e-cigarette use among 13–15 year-olds in 44 countries, finding that higher tax on combustible tobacco products was associated with higher adolescent e-cigarette use. Cerrai *et al*²¹ linked the Tobacco Control Scale with data from 15 to 16 year-olds in up to 30 European countries and concluded e-cigarette use had been associated with weaker tobacco control measures, especially on tobacco price, advertising and promotion. For smoking, there is robust evidence that higher level of implementation of key tobacco control policies is associated with lower smoking prevalence among adults^{22–24} and youth.²⁵ Yet, policy impact may differ contextually, making it important to consider factors such as country income level and socioeconomic factors in the examination of associations.

In this study, we aimed to answer the following research questions:

- ▶ Are there associations between national e-cigarette regulations and e-cigarette use among European youth aged 15–16 years when considering youth socioeconomic status (SES), perceived strength and enforcement of tobacco age-of-sale laws, country income level and general tobacco control progress in the country?
- ▶ Do the associations differ for ever and current use, and for exclusive e-cigarette use, exclusive cigarette use or dual use?

METHODS

Data sources

Individual-level data were obtained from the European School Survey Project on Alcohol and Other Drugs (ESPAD), which is a self-administered cross-sectional survey conducted every fourth year since 1995 to investigate substance use and its patterns among students aged 15–16 years. Its methodology and ethical compliance procedures in the participating countries have been described in detail elsewhere.⁴ In this study, we used data from 2019—when new core sections on the use of e-cigarettes were added to the questionnaire. Data on e-cigarette use were available from 35 countries with 102 484 students. On average, about 82% of the sampled schools (range 30%–100%) and 84% of the sampled classes (range 21%–100%) partook in the 2019 survey.⁴ Data on e-cigarette regulations were derived from the WHO Report on the Global Tobacco Epidemic 2021¹ and validated with the WHO European Office for the Prevention and Control of Noncommunicable Diseases. As the ESPAD data collection took place predominantly in March to May 2019,⁴ e-cigarette regulations which entered into force after that period were not

considered. Data on MPOWER policies were sourced from the WHO Global Health Observatory.²⁶ The country classification by income level came from the World Bank database as presented in the web annexes of the WHO Report on the Global Tobacco Epidemic 2021.¹ Out of 35 countries with the 2019 ESPAD data, 32 with 98 758 students had both individual-level and country-level data. Germany (Bavaria) (unweighted n=1459), Kosovo (unweighted n=1756) and Faroe Islands (unweighted n=511) were excluded from the original data set with 102 484 observations due to the lack of both individual-level and country-level data.

Outcome measures

Ever use ('lifetime' in the ESPAD terminology) was operationalised as ever use of e-cigarettes exclusively, ever use of cigarettes exclusively, ever dual use or never use of either product by combining adolescents' responses on whether they had ever used e-cigarettes and number of occasions (if any, ranging from 0=non-use to 1–40 or more) they had smoked cigarettes (excluding e-cigarettes) during their lifetime. Current use ('past-30-day-use' in the ESPAD terminology) was operationalised as exclusive e-cigarette use, exclusive cigarette use, dual use or none by combining adolescents' responses to the survey questions on whether they had used e-cigarettes and frequency of smoking cigarettes (ranging from 0=non-use to 1–more than 20 cigarettes per day) (excluding e-cigarettes) in the 30 days prior to the survey. For the logistic regression analyses, each of these nominal variables was dichotomised with youth reporting no ever or current use representing reference groups.

Individual-level measures

Sociodemographic measures included the survey respondent's gender (boy/girl), perceived family's financial well-being (how well-off an adolescent's family had been compared with other families in the country, from 0/very much less well-off to 6/very much better off) and parental education (having at least one parent with some college or university-level education). The measure of the perceived difficulty of getting cigarettes (excluding e-cigarettes) (from 0=don't know to 1=very easy to 5=impossible) was included as a proxy of the strength and enforcement of the tobacco age-of-sale laws in the country.

Comprehensiveness of e-cigarette regulations

Given the heterogeneity in the existence and scope of e-cigarette regulations, a new composite measure indicating the comprehensiveness of the national regulations was created for this cross-country study. The composite measure was based on the WHO MPOWER assessment applied to e-cigarette regulations reflecting policies implemented by the end of year 2020. Its methodology is detailed elsewhere.¹ We focused on the regulatory areas that have remained within national jurisdictions and are most relevant for the prevention of initiation considering the evidence, namely the indicators P (Protect from exposure), E (Enforce bans on advertising) and R (Raise taxes), and flavour regulations (F). For a country's composite score on regulations, P and E data were categorised following MPOWER classifications as 2=full (P: all public indoor places completely covered by bans on e-cigarette use; E: ban on all forms of direct and indirect advertising of e-cigarettes), 1=partial (P: ≥3 types of public indoor places covered completely by bans of e-cigarette use; E: advertising ban at least on national television, radio and print media) or 0=none. R and F data were categorised each as presence of respective regulation (1) versus lack thereof/no

data (0). Thus, counting together P, E, R and F, a country could receive a composite score between 0 and 6. In Montenegro, P, E and F regulations entered into force in August 2019 after the ESPAD data collection and were therefore coded as '0'.

General progress in tobacco control

To adjust for a country's general progress with tobacco control in the recent years, we created an indicator of a positive change (vs lack thereof or decrease) in a country's MPOWER score when it was higher in 2018 than 2014. The respective scores were composed of indicators for monitoring tobacco use and prevention policies, protecting from tobacco smoke, offering help to quit tobacco use, warning about the dangers of tobacco, enforcing bans on tobacco advertising and raising taxes on tobacco.^{1 26}

Country income level

Consistent with prior reports on higher prevalence of e-cigarette use in high-income countries,³ they were distinguished from middle-income economies based on the World Bank classification.¹ None of the ESPAD countries were low income.

Statistical analyses

Weighted percentages and corresponding 95% CIs were calculated to describe the crude prevalence of ever and current use of e-cigarettes and combustible cigarettes among adolescents and the remaining categorical variables. Means and 95% CIs were used to describe the score on e-cigarette regulations, perceptions of difficulty getting cigarettes and family's financial well-being. Two sets of multilevel binary logistic regression models with random intercept for countries were used for each outcome: first, including each independent variable by itself (results not shown), and second, including all independent variables as fixed effects simultaneously. All analyses were weighted consistent with the ESPAD methodology and conducted using Stata/SE V.14.2.⁴ Statistical significance level was set at 5%. All tests were two tailed.

RESULTS

Descriptive results

Across 32 European countries, less than half (48.8%) of adolescents aged 15–16 years had never used either cigarettes or e-cigarettes (table 1). Altogether, 13.3% had ever used cigarettes, 10.6% e-cigarettes and 27.3% both; and 13.0% currently used cigarettes, 6.0% e-cigarettes and 6.4% both. Country prevalence of e-cigarette use and smoking has been detailed in the ESPAD Report 2019 and by Cerrai and colleagues.^{4 21} Majority of adolescents (64.6%) had at least one parent in the family with some college or university-level education. On average, the adolescents perceived the financial well-being of their families to be the same or nearly better off compared with other families in their country (mean=3.6), and the difficulty of getting cigarettes as very or fairly easy (mean=1.6).

In terms of the protection from exposure, eight countries did not prohibit e-cigarette use in public indoor places, 21 countries had partial bans and three countries had full bans (table 2). Four countries had not enforced measures for advertising of e-cigarettes, 25 countries had partial advertising bans and three countries had full bans. Four countries have regulated e-cigarette flavours and 16 countries had raised excise taxes on e-liquids in closed or open systems. The average for the composite score on the comprehensiveness of the e-cigarette regulations was 2.58 (95% CI 2.12 to 3.04), with the highest score being found in

Table 1 Characteristics of the study population in 32 WHO European region countries, ESPAD 2019

| Characteristics | Weighted % or mean | 95% CI |
|---|--------------------|--------------|
| Ever use (%) | | |
| None | 48.8 | 44.5 to 53.1 |
| Exclusive e-cigarette | 10.6 | 9.0 to 12.5 |
| Exclusive cigarette | 13.3 | 11.1 to 15.9 |
| Dual use | 27.3 | 23.7 to 31.3 |
| Current use (%) | | |
| None | 74.6 | 71.5 to 77.4 |
| Exclusive e-cigarette | 6.0 | 4.9 to 7.3 |
| Exclusive cigarette | 13.0 | 11.1 to 15.1 |
| Dual use | 6.4 | 5.4 to 7.7 |
| Girls (%) | 50.8 | 50.2 to 51.4 |
| Parental college/high education in a family (%) | 64.6 | 59.4 to 69.5 |
| Perceived family's financial well-being rating (from 0=very less to 6=very much better off) | 3.6 | 3.5 to 3.7 |
| Perceived difficulty of getting cigarettes rating (from 0=don't know to 5=impossible), mean | 1.6 | 1.56 to 1.7 |
| World Bank country income group (%) | | |
| High-income economy | 78.3 | 57.4 to 90.6 |
| Middle-income economy | 21.7 | 9.4 to 42.6 |
| Unweighted number of observations=98 758; number of countries=32. | | |
| ESPAD, European School Survey Project on Alcohol and Other Drugs. | | |

Finland (5) and the lowest in Monaco (0). Between 2014 and 2018, altogether 25 countries (covering 77.5% of adolescents in our study) observed an increase in their MPOWER scores, and hence progressed in tobacco control in general.

Results from multivariable analyses

As shown in table 3, female adolescents had lower adjusted odds of ever ($OR_{adj}=0.50$; 95% CI 0.43 to 0.60) and current ($OR_{adj}=0.53$; 95% CI 0.45 to 0.63) use of e-cigarettes exclusively and as dual use, but higher prevalence of ever ($OR_{adj}=1.23$; 95% CI 1.10 to 1.37) and current ($OR_{adj}=1.17$; 95% CI 1.05 to 1.30) exclusive use of cigarettes compared with males (all $p<0.001$). Having at least one of the parents with some college or university-level education was associated with lower adjusted odds of ever and current use of e-cigarettes, cigarettes or dual use. A one-level increase in ranking of one's own family's financial well-being relative to other families in the country was associated with higher prevalence of current exclusive ($OR_{adj}=1.05$; 95% CI 1.01 to 1.08) and dual ($OR_{adj}=1.05$; 95% CI 1.00 to 1.10) use of e-cigarettes ($p=0.013$ and 0.045 , respectively). Perceiving more difficulties with obtaining cigarettes was associated with lower adjusted odds of ever and current use of e-cigarettes, cigarettes or both (all $p<0.001$): effect sizes ranged from 0.80 (95% CI 0.76 to 0.85) to 0.94 (95% CI 0.92 to 0.96).

When looking at the country-level characteristics, adolescents residing in middle-income versus high-income countries were less likely to use exclusively e-cigarettes or both products, ever and currently. However, adolescents residing in middle-income countries had 2.42 times the adjusted odds of ever using cigarettes exclusively (95% CI 1.27 to 4.61). A one-unit increase in the country's e-cigarette regulation score ranging from 0 to 5 was associated with lower prevalence of current ($OR_{adj}=0.78$; 95% CI 0.65 to 0.94) exclusive e-cigarette use and dual use ($OR_{adj}=0.80$; 95% CI 0.67 to 0.95). More details are reported in table 3.

Table 2 Description of selected tobacco control policies in 32 WHO European region countries with ESPAD 2019 data

| | E-cigarette regulations | | | | Score | MPOWER | | |
|-----------------|--------------------------|------------------|----------|--------------------|-------|--------|------|----------|
| | Protection from exposure | Advertising bans | Taxation | Flavour regulation | | 2014 | 2018 | Increase |
| Austria | Partial | Partial | No | No | 2 | 22 | 30 | Yes |
| Bulgaria | None | Partial | No | No | 1 | 28 | 30 | Yes |
| Croatia | Partial | Partial | No | No | 2 | 24 | 29 | Yes |
| Cyprus | Partial | Partial | Yes | No | 3 | 24 | 29 | Yes |
| Czechia | Partial | Partial | No | No | 2 | 26 | 30 | Yes |
| Denmark | Partial | Partial | No | Yes | 3 | 24 | 28 | Yes |
| Estonia | Partial | Partial | Yes | Yes | 4 | 23 | 30 | Yes |
| Finland | Partial | Full | Yes | Yes | 5 | 26 | 28 | Yes |
| France | Partial | Partial | No | No | 2 | 26 | 29 | Yes |
| Georgia | Partial | Partial | Yes | No | 3 | 20 | 31 | Yes |
| Greece | Full | Partial | Yes | No | 4 | 25 | 30 | Yes |
| Hungary | Partial | Partial | Yes | Yes | 4 | 28 | 28 | No |
| Iceland | Partial | Full | No | No | 3 | 24 | 24 | No |
| Ireland | None | Partial | No | No | 1 | 31 | 33 | Yes |
| Italy | Partial | Partial | Yes | No | 3 | 24 | 29 | Yes |
| Latvia | Partial | Partial | Yes | No | 3 | 26 | 29 | Yes |
| Lithuania | Partial | Partial | Yes | No | 3 | 24 | 27 | Yes |
| Malta | Full | Partial | No | No | 3 | 27 | 29 | Yes |
| Monaco | None | None | No | No | 0 | 12 | 10 | No |
| Montenegro | None | None | Yes | No | 1 | 25 | 25 | No |
| Netherlands | Partial | Partial | No | No | 2 | 25 | 28 | Yes |
| North Macedonia | None | None | Yes | No | 1 | 26 | 27 | Yes |
| Norway | Full | Partial | No | No | 3 | 30 | 30 | No |
| Poland | Partial | Partial | No | No | 2 | 24 | 28 | Yes |
| Portugal | Partial | Partial | Yes | No | 3 | 26 | 29 | Yes |
| Romania | Partial | Partial | Yes | No | 3 | 25 | 29 | Yes |
| Serbia | None | Partial | Yes | No | 2 | 24 | 24 | No |
| Slovakia | None | Partial | No | No | 1 | 24 | 28 | Yes |
| Slovenia | Partial | Full | Yes | No | 4 | 22 | 28 | Yes |
| Spain | Partial | Partial | No | No | 2 | 29 | 31 | Yes |
| Sweden | None | Partial | Yes | No | 2 | 22 | 26 | Yes |
| Ukraine | Partial | None | No | No | 1 | 29 | 29 | No |

Data for e-cigarette regulations were derived from the WHO Report on the Global Tobacco Epidemic 2021,¹ validated with the WHO European Office for the Prevention and Control of Noncommunicable Diseases (NCD Office), and data for MPOWER from the WHO Global Health Observatory.²⁶ The development of the e-cigarette regulation score and the MPOWER positive change score has been described in the Methods section. The MPOWER 2014–2018 positive change score is calculated from the following indicators: monitoring tobacco use and prevention policies, protecting from tobacco smoke, offering help to quit tobacco use, warning about the dangers of tobacco, enforcing bans on tobacco advertising and raising taxes on tobacco.

ESPAD, European School Survey Project on Alcohol and Other Drugs.

DISCUSSION

We have found that more comprehensive national e-cigarette regulations were associated with lower risk of current exclusive e-cigarette use and dual use among youth. These associations were observed adjusting for individual characteristic and SES, country income level and general tobacco control progress in the country. Additionally, we have found that higher perceived difficulty of obtaining cigarettes among youth, a proxy for the strength of the age-of-sale laws in the country, was associated with lower likelihood of ever and current use of cigarettes, e-cigarettes and both products.

To our knowledge, this is the first cross-country study to address the role of e-cigarette-specific regulations in the prevention of e-cigarette use among adolescents. Findings from previous studies on tobacco product regulations in connection to youth e-cigarette use were inconsistent,^{20,21} highlighting the need to address product-specific regulations and their effectiveness with more countries adopting them. Some country examples already indicate the importance of adopting and implementing comprehensive regulations

to prevent youth e-cigarette use. For instance, in Finland, where e-cigarettes were subject to the same regulatory scheme as tobacco products in 2016—including retail sale licence, age limit, point-of-sale display and advertising ban, bans of e-cigarette use in smoke-free areas and ban on other than tobacco flavours in e-liquids, in addition to the pre-existing general advertising ban—the daily use of products has been decreasing steadily among youth.¹⁸ In the USA, declines in youth e-cigarette use after earlier increase were reported in connection with federal-level regulations on flavours and age of sales implemented in 2019–2020.^{9, 17, 19} However, the changes may also relate to the COVID-19 pandemic, e-cigarette or vaping product use-associated lung injury (EVALI) outbreak and the Food and Drug Administration's prevention campaign,^{9, 11, 19} warranting further monitoring and research.

Overall, the associations on ever and current use found in our study were quantitatively similar by type of product, which speaks to importance of addressing similar determinants in interventions and policies for cigarettes and e-cigarettes. However,

Table 3 Adjusted association of individual-level and country-level characteristics with use of e-cigarettes and cigarettes in WHO European region countries, ESPAD 2019

| | Current use (ie, past 30 days) (vs none) | | Ever use (vs none) | |
|---|--|---------------------------|-----------------------------|---------------------------|
| | E-cigarettes OR (95% CI) | Cigarettes OR (95% CI) | E-cigarettes OR (95% CI) | Cigarettes OR (95% CI) |
| Individual level | | | | |
| Girls (vs boys) | 0.53*** (0.45 to 0.63) | 1.17** (1.05 to 1.30) | 0.50*** (0.43 to 0.60) | 1.23*** (1.10 to 1.37) |
| High education in the family (vs primary/secondary) | 0.86*** (0.79 to 0.94) | 0.81*** (0.76 to 0.87) | 0.90* (0.82 to 0.98) | 0.85*** (0.79 to 0.92) |
| Perceived family's financial well-being (continuous, from lowest to highest) | 1.05* (1.01 to 1.08) | 0.99 (0.97 to 1.01) | 1.03 (1.00 to 1.07) | 0.96** (0.94 to 0.99) |
| Perceived difficulty of getting cigarettes (continuous, from lowest to highest) | 0.91*** (0.88 to 0.95) | 0.87*** (0.82 to 0.91) | 0.94*** (0.92 to 0.96) | 0.91*** (0.89 to 0.93) |
| Country level | | | | |
| Score on e-cigarette regulations (continuous) | 0.78* (0.65 to 0.94) | 0.96 (0.79 to 1.15) | 0.86 (0.74 to 1.01) | 0.98 (0.81 to 1.18) |
| MPOWER score 2014–2018 increase (vs no/decrease) | 0.66 (0.40 to 1.06) | 2.02 (0.83 to 4.93) | 0.79 (0.51 to 1.23) | 2.34 (0.88 to 6.22) |
| Middle-income country group (vs high) | 0.33*** (0.19 to 0.58) | 1.51 (0.80 to 2.84) | 0.40** (0.21 to 0.75) | 2.42** (1.27 to 4.61) |

All listed variables were included as fixed effects in each of the six weighted multilevel models with a country random intercept. Starting from the multivariable model on current e-cigarette use (from left to right), the unweighted numbers of observations were 64 182; 69 459; 64 480; 67 085; 49 096; and 60 578 from 32 countries.
***p<0.001; **p<0.01; *p<0.05.
ESPAD, European School Survey Project on Alcohol and Other Drugs.

given the relatively high prevalence of dual ever use among youth, addressing it and its health risks and consequences, including those related to nicotine addiction, warrants more attention in designing preventive interventions. Our findings remind us of the importance of socioeconomic circumstances on both individual and macro levels in preventing the use of tobacco and nicotine-containing products in adolescence, and in understanding of the policy impact. As comprehensive e-cigarette regulations are important across socioeconomic characteristics and country income levels, more attention is needed to develop and evaluate tobacco control interventions for youth with different socioeconomic backgrounds. Similar to other studies on youth smoking in Europe,²⁵ we have found higher levels of parental education were protective of ever and current smoking, e-cigarette use and dual use. Perceived family wealth was associated with higher likelihood of current exclusive and dual use of e-cigarettes and lower ever use of cigarettes in our study. Prior research has also suggested e-cigarette use at least partially related to higher SES.^{7, 27} On the country level, the prevalence of e-cigarette use has been lower among youth in the middle-income and low-income than high-income countries³; however, to contain the situation, 'proactive' rather than 'reactive' regulations are needed.^{28, 29}

While our study has several strengths including the recent large youth data from 32 European countries collected with the standardised ESPAD methodology and recent national e-cigarette regulation data assessed with the standardised WHO MPOWER methodology, some limitations need to be noted. First, the school and class participation rates vary between countries, and the results can only be considered representative for students in public schools. However, a simulation study of German ESPAD data showed non-participation of schools had not largely affected the validity of resulting prevalence estimates.³⁰ Second, we were able to consider only dual use rather than multiple product use in the 32 study countries as questions on other tobacco products are optional. Similarly, to ensure enough observations for comparative and multivariable analyses and reduce potential information bias, we did not examine levels or frequency of use. Next, measurement of youth SES continues to pose challenges. Multiple SES measures such as those of the child, the parents and the family have been suggested to be more informative.^{31, 32} Hence, we included an adolescent's perceived financial well-being of the family in addition to parental educational level, recognising the subjective nature of the variable. Additionally, given the cross-sectional nature of the ESPAD data, causal inferences cannot be made.

Furthermore, while the WHO MPOWER data collection includes a data validation procedure with country representatives, differences in interpretations of the policies are possible and may remain in the final data. Given the large variation in the e-cigarette products, and the coverage and scope of their national regulation, our cross-country comparisons with the composite score of selected tobacco control measures applied to e-cigarettes did not attempt to assess or compare the effectiveness of specific regulations. This remains a topic for further research following more widespread implementation of these policies.

In conclusion, implementing comprehensive regulations for e-cigarettes—addressing e-cigarette use in public indoor places, advertising and taxation of the products and regulation of flavours—may be protective against e-cigarette use and dual use among adolescents. Further, efforts to prevent youth access to cigarettes remain important as perceived difficulty in obtaining them can have cross-product influences. Given the current easy under-age access to e-cigarettes,¹³ calibrating the regulations

on e-cigarette sales with those on cigarette sales with strong enforcement may be beneficial for preventing e-cigarette use. In Europe, strengthening e-cigarette regulations as part of the revisions of the European Union directives on tobacco products, tobacco taxation and tobacco advertising, and the council recommendation on smoke-free environments, could benefit countries that have until now addressed the key regulatory areas in less comprehensive manner in their national legislation.

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Contributors The study was conceptualised by HO, YT and AC. KR provided the ESPAD data, and AC and EL provided the WHO data. Analysis was conducted by YT. HO was the lead author of the manuscript and all authors contributed to the writing of this manuscript. All authors have reviewed the manuscript. HO acts as guarantor for the article.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval The ESPAD study involves human participants and the ethics committee(s) or institutional board(s) procedures vary in the participating countries. A reference has been provided in the manuscript that provides details of the approval types in the participating countries. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. Data may be obtained from a third party and are not publicly available. WHO MPOWER data are publicly available in the WHO Global Health Observatory and in WHO Report on the Global Tobacco Epidemic 2021. The ESPAD survey has a protocol for applying the international data by ESPAD and non-ESPAD researchers. More information is available at <http://www.espad.org/databases>.

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