Trends in smoking prevalence among 14–15-year-old adolescents before and after the emergence of vaping in New Zealand; an interrupted time series analysis of repeated cross-sectional data, 1999–2023

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Summary

Background New Zealand experienced a prolonged period of minimal regulation on e-cigarettes until the passing of the 2020 Smokefree Environments and Regulated Products (Vaping) Amendment Act.

Methods Interrupted time series analyses of the Action for Smokefree 2025 (ASH) Year 10 Snapshot Survey data from 1999 to 2023 to compare changes in smoking trends among 14–15-year-old students (n = 690,470) before and after the advent of vaping in New Zealand (around 2010).

Findings The prevalence of daily-vaping increased from 1.1% in 2015 (the first year the question was asked) to 1.8% in 2018 before rising to 10.0% in 2023, a nine-fold increase over eight years. From 1999 to 2023, considerable declines in ever-, regular-, and daily-smoking prevalence were observed. However, the rates of decline in ever- and regular-smoking slowed significantly from 2010 onwards ($p < 0.001$ for both), coinciding with the advent and rapid growth of vaping among New Zealand adolescents. In contrast, the rate of decline in daily-smoking did not significantly change from 2010 onwards ($p = 0.066$). These findings were robust to sensitivity analyses, including the use of different time series interruption points (change-years) and controlling for inflation-adjusted cigarette prices.

Interpretation Our findings starkly contrast with those from a previous analysis of ASH data, which suggested that e-cigarettes appear to be displacing smoking among New Zealand youth. Instead, our findings suggest that among 14–15-year-olds, the rapid rise of vaping may have slowed the rates of decline in ever- and regular-smoking, while having little or no impact on the rate of decline in daily smoking. Our findings underscore the importance of effective policy approaches to curb both adolescent vaping and smoking.

Funding None.

Keywords: Adolescents; Smoking; Tobacco; Vaping; e-cigarettes; New Zealand; Interrupted time series; Segmented logistic regression

Introduction

New Zealand (Aotearoa) serves as a potentially useful case study for examining the impacts of an extended period of a lightly regulated e-cigarette market on patterns of adolescent e-cigarette usage (vaping) and tobacco smoking. Emerging around 2010, New Zealand's e-cigarette market initially functioned in a legal grey area due to the absence of specific regulations tailored for the sales or usage of e-cigarettes. It was generally assumed that nicotine-containing e-cigarettes were covered under existing tobacco and medicine laws, prohibiting their sale unless approved for therapeutic purposes by Medsafe, the country's medicines regulator (with an exception for the importation of up to three months' supply of nicotine

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Research in context

Evidence before this study

We searched PubMed up to August 2024 using the following search terms ("e-cigarettes" OR "vaping") AND ("smoking" OR "tobacco use") AND ("adolescents" OR "youth") AND ("cross-sectional" OR "population-level" OR "population-based" OR "ecological" OR "longitudinal" OR "cohort") AND "New Zealand". Two studies were identified, of which only one was a cross-sectional, population-level, longitudinal or cohort study attempting to assess the potential association between vaping and smoking among New Zealand adolescents. The study concluded that the overall decline in smoking between 2014 and 2019 among New Zealand 14–15-year-olds suggests that e-cigarettes might be displacing smoking.

Added value of this study

Our study used the same data source as the previous New Zealand study mentioned above but expanded the analysis period to include 1999–2023. In stark contrast to the conclusion of the previous study, we found that among 14–15-year-olds, the emergence and rapid rise of vaping in New Zealand may have slowed the rates of decline in ever- and regular-smoking, while having little or no impact on the rate of decline in daily smoking.

Implications of all the available evidence

Our findings underscore the importance of effective policy approaches to curb both vaping and smoking among New Zealand adolescents.

e-liquids for personal use).[1,2] Despite the nicotine-content restrictions, there was evidence that nicotine-containing e-cigarettes were still being obtained and used.[3] Moreover, non-nicotine-containing e-cigarettes were not assumed to be covered under existing laws, leaving their sale relatively unrestricted. By 2017, nearly 1 in 3 year 10 students aged 14–15 had tried vaping, and 6.5% were vaping regularly (daily, weekly, or monthly).[4]

In March 2018, the regulatory landscape shifted toward even less regulation following a district court's ruling in favour of Philip Morris.[5] The court decided that existing tobacco legislation did not cover aerosol products like e-cigarettes, leading to a two-and-a-half-year period of open sales and marketing of e-cigarettes, including those containing nicotine, with minimal restrictions.[6,7] Following the court ruling, the proportion of adolescent e-cigarette users using nicotine-containing e-cigarettes increased; in 2018, only 23% of 14–15-year-old current e-cigarette users reported vaping nicotine in their last vape,[8] whereas in 2019, 90% of 13–18-year-olds who vaped weekly reported using nicotine-containing e-cigarettes.[9] General e-cigarette usage among 14–15-year-olds also rose sharply, with the proportion who used them regularly increasing from 7.4% in 2018 to 12.0% in 2019.[4] It was not until late 2020, when the New Zealand parliament enacted the Smokefree Environments and Regulated Products (Vaping) Amendment Act, that the existing tobacco legislation was extended to include vaping and e-cigarettes.[10] The 2020 Amendment Act intended to limit advertising and enforce stricter controls on the sale and supply of nicotine-infused products, and aimed to curb the widespread use of e-cigarettes, especially among young people.[11] Notwithstanding the 2020 Amendment Act, New Zealand's extended period of light regulation and lenient enforcement for more than a decade provides researchers with a valuable context for evaluating the potential public health consequences—both positive and negative—of allowing an e-cigarette market to proliferate with relatively few constraints.

One such area of research where New Zealand's light e-cigarette regulations could provide useful insights is examining the potential impact of vaping on adolescent smoking rates. Individual-level prospective cohort studies conducted in other countries have consistently found strong positive associations between the initiation of vaping and subsequent smoking among adolescents[12,13] (although some authors have questioned the causal interpretation of these associations).[14,15] However, no such individual-level studies have been conducted in any New Zealand cohort. With regard to repeated cross-sectional data analysis, only one study has attempted to link population-level vaping and smoking trends among New Zealand adolescents.[16] In that study, however, the analysis of smoking prevalence data was restricted to the years 2014–2019, many years after vaping had established a notable presence in New Zealand. Importantly, the analysis did not assess whether smoking trends changed before and after shifts in vaping prevalence, an essential requirement for evaluating the population-level impacts of vaping on smoking.

To address this key limitation, our study uses the same data source as the previous New Zealand study but expands the analysis period to include 1999–2023. With this extended data spanning before and after the emergence of vaping in New Zealand in about 2010, we employed an interrupted time series approach similar to analysis conducted in the United States (US) and United Kingdom (UK).[17–20] This approach allowed us to compare adolescent smoking trends in New Zealand before and after vaping's proliferation to evaluate its potential impacts on these trends.

Methods

Study design and participants

The Action for Smokefree 2025 (ASH, formerly Action on Smoking and Health) Year 10 Snapshot Survey of year 10 students in New Zealand is a repeated cross-sectional survey that began in 1992 and has been running annually since 1999, except for 2020 due to COVID-19 interruptions. The survey is one of the largest ongoing youth smoking surveys in the world, with between 20,000 and 33,000 participants per year (about 35–50% of the national year 10 population). In 2014, a question was added asking students if they had ever tried an e-cigarette and questions about frequency of e-cigarette use were added to the 2015 survey. All schools with year 10 students are invited to participate each year, other than distance education schools. The survey is a self-administered, pen-and-paper questionnaire completed by students in classroom settings under teacher supervision. Completed questionnaires are securely collected and returned to ASH via courier for processing. Further details on the ASH survey methodology are described elsewhere.[21] For the current analyses, we used publicly available population-level data from the ASH Snapshot surveys from 1999 to 2023 for year 10 students aged 14–15 years[4] and Consumer Price Index (CPI) data for 'all groups combined' —i.e. all goods and services in the CPI—and for 'cigarettes and tobacco' from 1999 to 2023.[22] Prevalence estimates for smoking and vaping reported by ASH necessarily exclude missing data, which external reporting suggests is very low at less than 2%.[16] Data collection for the ASH study was conducted with the approval of the Multi-region Ethics Committee (MEC/07/10/141). Our analysis used publicly available population-level data from the ASH study, requiring no direct ethics approval.

Measures

Students were categorised as having 'ever-smoked' if they responded 'yes' to the question, 'Have you ever smoked a cigarette, even just a few puffs?' Similarly, those who answered 'yes' to 'Have you ever tried electronic cigarettes (even just a single puff or vape)?' were classified as having 'ever-vaped'. Students reporting smoking and/or vaping 'At least once a day' were categorised as 'daily-smoking' and/or 'daily-vaping', respectively. 'Regular-smoking' and 'regular-vaping' were defined as engaging in smoking and vaping at least daily, weekly, or monthly.

Statistical methods

'Crude prevalence' estimates for smoking and vaping correspond to simple unadjusted percentages. Segmented logistic regression (interrupted time-series) analysis was used to assess whether the rates of decline in the prevalence of three smoking outcomes—ever-smoking, regular-smoking, and daily-smoking—have changed since the year e-cigarettes started being used at non-trivial levels across New Zealand. This year is termed the 'change-year' in the regression models. However, choosing the most appropriate change-year is not straightforward because, like many countries, New Zealand did not begin surveying adolescents about their vaping behaviours until after vaping had become widespread. Specifically, the Youth Insights Survey (YIS) was the first in New Zealand to ask about e-cigarette use and found 7% of 14–15-year-olds had tried an e-cigarette by 2012. Given the absence of vaping prevalence estimates before 2012, we selected 2010 as the change-year for New Zealand, drawing on global trends from countries like the US and regions within the UK, where e-cigarette use among youth began reaching noticeable levels around 2010/2011.[23,24] Specifically, for each of the smoking prevalence outcomes (ever-smoking, regular-smoking, and daily-smoking), the segmented logistic regression models were specified as:

$$\text{Logit}\,(\text{crude} - \text{smoking} - \text{prevalence}_{\text{year}}) = \alpha + \beta 1 \text{background} - \text{trend}_{\text{year}} + \beta 2 \text{vaping–trend}_{\text{year}}$$

where crude-smoking-prevalence$_{\text{year}}$ is incorporated in the model using the full sample size of observed counts $n_{\text{year}}/N_{\text{year}}$ (n_{year} is the number of 14- to 15-year-olds experiencing the smoking outcome in that year, and N_{year} is the total number of 14- to 15-year-olds surveyed); background-trend$_{\text{year}}$ = 1,…,25 corresponding to ASH survey years 1999,…,2023 (excluding 2020 when there was no survey due to COVID-19); and vaping-trend$_{\text{year}}$ takes the value 0 before 2010 followed by single year increases (excluding the COVID-19 year). Heteroskedasticity- and autocorrelation-consistent (HAC) standard errors were used to account for potential autocorrelation.

In these models, 1999 was chosen as the model 'start-year' since the prevalence of regular-smoking among adolescents in New Zealand began declining from this year onwards.[25] 'Smoothed' smoking prevalence estimates (%) from 1999 to 2023 were calculated using model-estimated values. The 'background trend' represents estimates with the vaping-trend parameter (β2) set to 0, projecting the pre-2010 smoking trend forward as if vaping had no influence on smoking rates. The 'observed trend' represents estimates with all model parameters, reflecting the actual smoking trend observed from 2010 onwards including the impacts of vaping. Smoothed background and observed smoking prevalence estimates (%) for 2023 are denoted B_{23} and O_{23}, respectively. Excess numbers of students in 2023 who experienced each smoking outcome per 1000 students due to changes in the observed trend at the change-year were calculated as $E_{23} = 10 \times (O_{23}–B_{23})$, with negative values corresponding to fewer experiencing the smoking outcome.

Four sets of sensitivity analyses were performed. First, to avoid potential post-publication disagreements with our choice of change-year = 2010 and start-year = 1999, we re-fitted the segmented regression models with change-year values ranging from 2008 to

2018, and with start-year values ranging from 1999 to 2003. This range of change-years reflects the inherent uncertainty in identifying the year when vaping began influencing smoking trends. Similarly, the range of start-year accounts for potential concerns that certain start-years may not be consistent with the general downward trend observed in smoking prevalence before 2010. Second, as another method to account for autocorrelation besides using HAC standard errors, we included crude-smoking-prevalence$_{year-1}$ as a covariate in our logistic regression models (although for 2021, we used crude-smoking-prevalence$_{2019}$ because the survey was not conducted in 2020 due to COVID-19). This method corresponds to autoregressive models, specifically AR1 (one lag), incorporating previous observations to predict current outcomes.[26] It serves as an additional check on our primary method for handling autocorrelation since there is no consensus on the best method for addressing autocorrelation with binary outcomes. Third, we calculated the relative price index of cigarettes and tobacco as the ratio of the CPI for cigarettes and tobacco to the CPI for all groups combined, covering the years 1999–2023. We then multiplied this index by the nominal price of a packet of 25 cigarettes in 2017—the base year for the CPI data—to derive an inflation-adjusted cigarette pack price for each year. Subsequently, we re-fitted our segmented regression models, including the log of inflation-adjusted cigarette pack prices in the regression models (to assess the potential confounding effects of cigarette price changes on smoking trends). Fourth, we conducted a sensitivity analysis excluding data after 2019 to account for the potential distorting influence of the COVID-19 pandemic on our findings, extrapolating excess number estimates to 2023 for comparative purposes.

Role of the funding source

No funding was provided for this specific project.

Results

A total of 690,470 New Zealand year 10 students from 1999 to 2023 were included in the analyses (Table 1). Forty-nine percent were male, 50.7% female, and 0.3% identifying as non-binary. Regarding ethnicity, roughly 20% reported as Māori, 8% as Pacific, and 72% as non-Māori/non-Pacific (predominantly European).

Characteristic	n	% (valid responses)
Total	690,470	100%
Gender		
Male	338,467	49.0%
Female	349,952	50.7%
Non-binary	2051	0.3%
Ethnicity		
Māori	123,001	19.5%
Pacific	52,740	8.3%
Non-Māori non-Pacific	456,499	72.2%
Not reported[a]	58,230	–
Period		
1999–2009	328,955	47.6%
2010–2023	361,515	52.4%

[a]Ethnicity breakdowns not reported for 1999 and 2000.

Table 1: **Gender and ethnicity distributions of ASH Year 10 Snapshot Survey participants aged 14–15 years, 1999–2023.**

The (crude) prevalence of students who had ever-vaped increased from 20.8% in 2014 to 42.7% in 2021, and then declined to 37.5% in 2023, a relative increase of 80% over the nine-year period (Fig. 1). Regular-vaping (daily, weekly, or monthly) prevalence increased from 3.5% in 2015 to 20.2% in 2021, and then declined to 16.4% in 2023, corresponding to a 4.5-fold increase over the eight-year period. Daily-vaping increased from 1.1% in 2015 to 1.8% in 2018, and then saw a substantial rise to 10.0% by 2023, a nine-fold increase over the eight-year period. These 2023 prevalences equate to 100 per 1000 year 10 students vaping daily, 164 per 1000 vaping regularly, and 375 per 1000 having tried vaping.

In 1999, 68.4% of year 10 students had tried smoking, 28.6% smoked regularly, and 15.6% smoked daily (Fig. 2, crude prevalences and Supplementary Figure S4). By 2023, these prevalences had declined considerably to 12.2%, 2.8%, and 1.2%, respectively. These changes represent relative declines of 82.2% for ever-smoking, 90.2% for regular-smoking, and 92.3% for daily-smoking over the 25-year period.

The segmented logistic regression analysis indicated significant changes in smoking prevalence trends among 14–15-year-olds from the change-year (2010) onwards (Fig. 2). For ever-smoking (Fig. 2A), the slope of the 'smoothed' observed prevalence trend (solid line) deviated upwards significantly from the projected background trend (dashed line) in 2010 ($p < 0.001$). This deviation corresponds to a significant change in the linear trends of the log-odds of ever-smoking (linearity in the log–odds scale is due to the logit transformation in logistic regression). By 2023, the estimated (smoothed) prevalence of ever-smoking was 12.6% (95% CI [11.3, 13.9]) based on the 'smoothed' observed trend, compared to 6.6% (95% CI [5.5, 7.9]) for the projected background trend in the hypothetical absence of vaping. This amounts to an excess of 60 more year 10 students per 1000 in 2023 who had tried smoking than was expected, if ever-smoking rates had continued along the pre-vaping era trajectory (shaded cell in Supplementary Table S1).

For regular-smoking (Fig. 2B), the slope of the observed trend (solid line) again showed a significant upward deviation from the projected background trend (dashed line) in 2010 ($p < 0.001$). By 2023, the estimated (smoothed) prevalence of regular-smoking was 3.0% (95% CI [2.6, 3.5]) based on the 'smoothed' observed

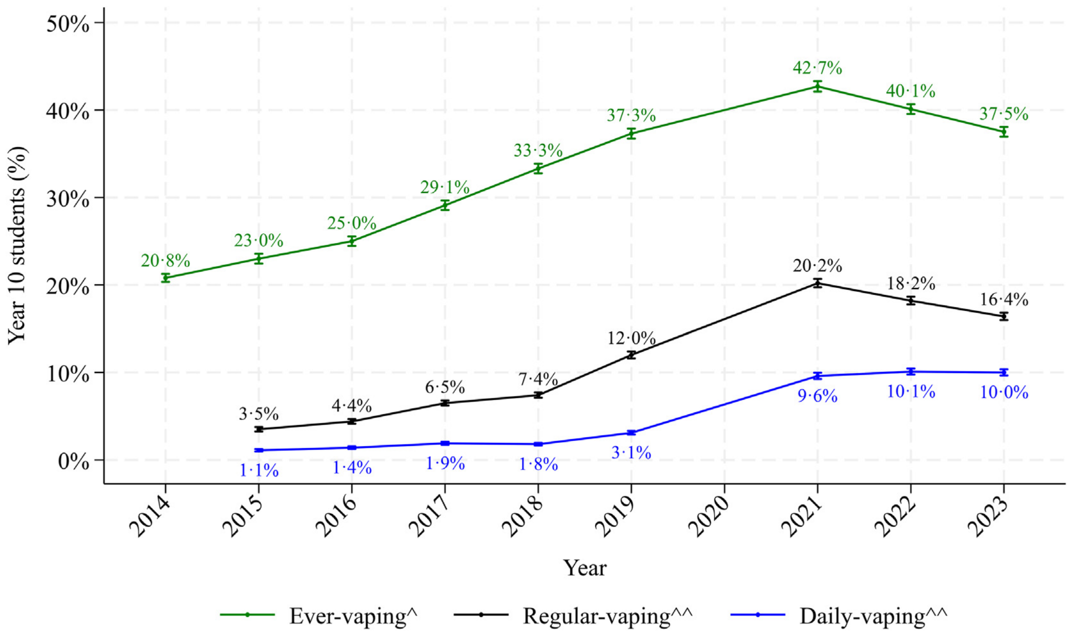

Fig. 1: **Crude prevalence of ever-vaping, regular-vaping, and daily-vaping among year 10 students aged 14–15 years in New Zealand, 2014–2023.** ^Question added to the ASH surveys from 2014. ^^Questions added to the ASH surveys from 2015.

trend, compared to 1.8% (95% CI [1.6, 2.1]) for the projected background prevalence in the hypothetical absence of vaping. This translated to an excess of 12 more year 10 students per 1000 smoking regularly in 2023 than expected had regular-smoking rates continued along the pre-vaping era trajectory (shaded cell in Supplementary Table S2).

For daily-smoking (Fig. 2C), in contrast to the higher observed prevalence trends seen for ever-smoking and regular-smoking, the observed trend (solid line) deviated downwards from the projected background trend (dashed line) from 2010, although this change was not statistically significant (p = 0.066). By 2023, the estimated (smoothed) prevalence of daily-smoking was 1.0% (95% CI [0.9, 1.1]) based on the 'smoothed' observed trend, compared to a higher 1.2% (95% CI [1.1, 1.4]) for the projected background prevalence in a hypothetical scenario without vaping. This amounted to 2 fewer year 10 students per 1000 smoking daily in 2023 than expected had daily-smoking rates followed the pre-vaping trajectory (shaded cell in Supplementary Table S3).

In sensitivity analyses, depending on the choice of change-year or start-year, the excess number of year 10 students who had ever-smoked in 2023 ranged from 47 to 81 per 1000 (Supplementary Table S1). For regular-smoking, the excess ranged from 9 to 16 per 1000 (Supplementary Table S2). For daily-smoking, the change ranged from 3 fewer to an excess of 2 per 1000 (Supplementary Table S3). In general, the choice of change-year and start-year did not substantively alter our overall findings. For the sensitivity analyses using lagged smoking prevalence as a covariate (AR1 analysis), the results were similar to the main analysis (Supplementary Figure S1). However, the changes in the rates of decline in smoking prevalence from 2010 were marginally less pronounced, with a smaller reduction in the rate of decline of daily-smoking prevalence, and smaller increases in the rates of decline of ever- and regular-smoking prevalence. In the sensitivity analysis that adjusted for inflation-adjusted cigarette pack prices, the 2023 prevalence point estimates closely aligned with those from the main analysis, indicating that price was not a confounding factor (Supplementary Figure S2). In the sensitivity analysis excluding data after 2019, the extrapolated 2023 prevalence point estimates closely aligned with those from the main analysis, indicating that the observed change in trends from 2010 were not influenced by pandemic-related disruptions (Supplementary Figure S3).

Discussion

Vaping among 14–15-year-old year 10 students in New Zealand has dramatically increased in recent years, with daily-vaping increasing ninefold and regular-vaping rising 4.5-fold between 2015 and 2023. Moreover, our interrupted time series analysis indicates that by 2023, considerably more students had tried smoking and were regularly smoking than would have been expected if pre-vaping era smoking trends had continued beyond 2010. On the positive side, however, our results suggest that

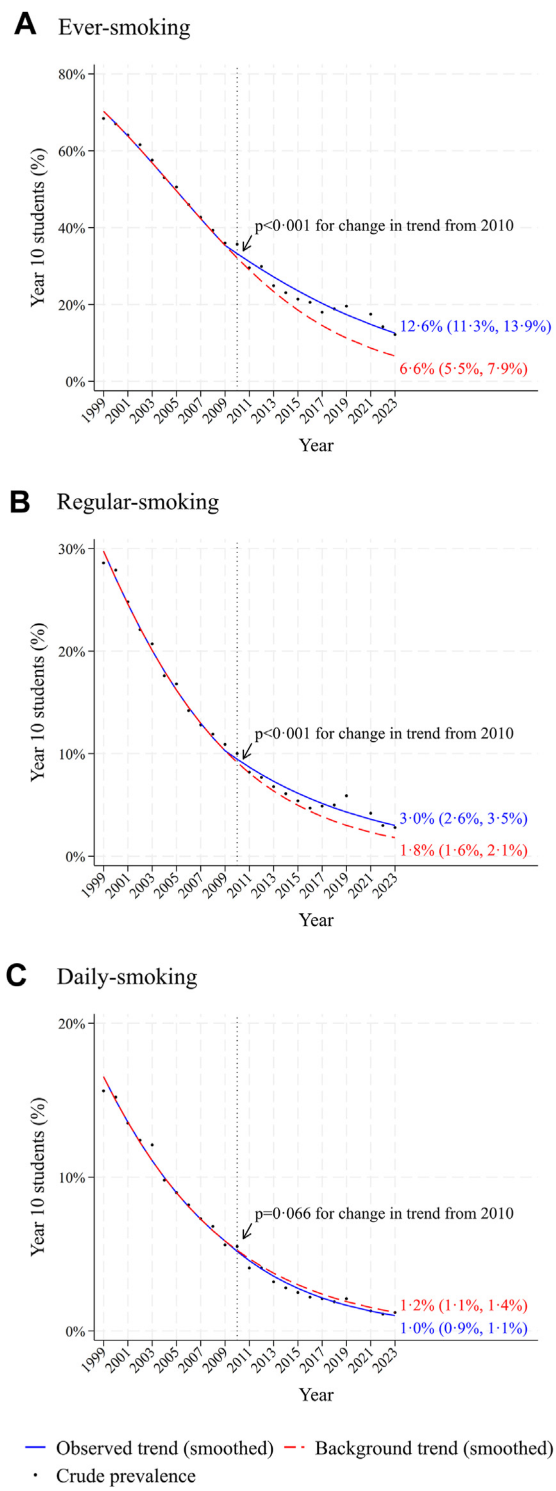

Fig. 2: **Observed and background trends estimated from segmented logistic regression models, and crude prevalence for A) Ever-smoking, B) Regular-smoking, C) Daily-smoking**.

the number of students smoking daily was slightly lower than anticipated based on the pre-vaping era daily-smoking trend, albeit with some uncertainty (p = 0.066).

Our findings contrast with those of a 2020 study mentioned in the introduction,[16] despite both using ASH data. In the 2020 study, it was concluded that the "*...overall decline in smoking over the past 6 years in New Zealand youth suggests that e-cigarettes might be displacing smoking*". This conclusion was surprising, however, as it was based solely on the observation of declining smoking rates from 2014 to 2019, a period when e-cigarette use had already become notably present among New Zealand youth. By not assessing whether smoking trends *changed* rather than simply *declined*, the study incorrectly attributed the observed declines between 2014 and 2019 to vaping, without considering whether these declines reflected a continuation—or even a slowing—of pre-existing declines. In contrast, our analysis of ASH smoking data over an extended timeframe—including before the introduction of vaping in New Zealand around 2010—showed that the rates of decline for both ever- and regular-smoking significantly slowed from 2010 onwards. In this context, our findings not only challenge the displacement theory suggested by the 2020 study, but they in fact suggest the opposite—that vaping might be increasing the risk of ever-smoking and regular-smoking among New Zealand year 10 students. While we also observed a possible small displacement effect for daily-smoking, the broader implications must be considered. Specifically, the small and uncertain estimated decrease in daily-smoking rates by 2023–2 fewer students per 1000—needs to be weighed against the estimated increases in regular-smoking (12 per 1000), ever-smoking (60 per 1000), daily-vaping (100 per 1000), regular-vaping (164 per 1000), and ever-vaping (375 per 1000).

The difference between our interpretation of the ASH data and that of the 2020 study is not merely an artefact of the 2020 study lacking access to data beyond 2019. Indeed, when we excluded data after 2019, we still observed a similar slowing in the rates of decline for ever-smoking and regular-smoking (Supplementary Figure S3). The key issue is that the conclusion of the 2020 study was simply not supported by its results. Correcting the record of the 2020 study is particularly important, as it has been repeatedly cited to lobby government committees and influence policy decisions. Notably, it was the most frequently cited piece of evidence in submissions to the New Zealand Parliament's Health Select Committee—including by British American Tobacco (BAT)—regarding a 2020 Bill that preceded the 2020 Amendment Act, which aimed to regulate the sale and marketing of e-cigarettes.[7] Furthermore, in its submission to the Australian

Parliament's Select Committee on Tobacco Harm Reduction, BAT again referenced the 2020 study as important evidence to argue against the tightening of e-cigarette regulations.[27] In its submissions to both committees, BAT quoted verbatim the unsubstantiated claim from the 2020 study mentioned above (i.e. "*The overall decline in smoking over the past 6 years in New Zealand youth suggests that e-cigarettes might be displacing smoking*").[7,27]

Although this is the first interrupted time series analysis comparing adolescent smoking trends before and after the advent of vaping in New Zealand, similar analyses in the US and UK have yielded mixed—and sometimes hotly debated—findings. Using data from the National Youth Tobacco Surveys (NYTS) spanning 2004 to 2014, a 2017 US study by Dutra and Glantz examined 6th- to 12th-graders and found that ever- and current-smoking decreased linearly between 2004 and 2014, with no significant changes in these trends after 2009 (the year deemed as the change-year by the authors).[17] In contrast, a 2019 study by Levy et al. analysed multiple US data sets (including NYTS data) and found that the decline in smoking rates among US youth appeared to have accelerated from 2014 (their change-year).[18] The disagreement on the appropriate change-year was articulated in exchanges between Glantz and Levy following the publication of the Levy et al. study.[28] In these exchanges, Glantz critiqued the 2014 change-year chosen by Levy and advocated for 2009 based on early e-cigarette availability in the US, while Levy countered that vaping was not prevalent enough before 2014 to influence smoking trends. In our study, to avoid limitations associated with selecting a single change-year, we conducted sensitivity analyses by re-fitting the segmented regression models with change-years ranging from 2008 to 2018 (Supplementary Tables S1–S3). Regardless of the year chosen, our results were similar thus mitigating concerns about potential bias introduced by choosing specific change-years.

Another notable interrupted time series analysis was conducted in 2020 in the UK using repeated cross-sectional data from 248,324 young people aged 13 and 15 years, collected between 1998 and 2015.[19] The study used 2011 as their change-year and found a significant slowing in the rate of decline for regular-smoking from 2011, which is broadly consistent with our New Zealand results. Despite their finding, the authors suggested that the slowing rate of decline for regular-smoking was probably not due to vaping, as they also observed slowing rates of decline of cannabis and alcohol use, interpreting this as part of a broader trend across substance use behaviours. However, this interpretation overlooks the possibility that vaping and tobacco smoking could be exerting a broader influence on other substance use, particularly for substances like cannabis, which is commonly smoked, often mixed with tobacco, and can also be vaped.[29] Supporting this notion, a 2019 systematic review and meta-analysis of three longitudinal studies found that the odds of cannabis use were 2.4 times higher for US adolescents who had previously used e-cigarettes,[30] while other longitudinal studies have found significant positive associations between vaping and subsequent alcohol use.[31,32] Therefore, while the authors of the UK study attributed the slowing in the rate of decline in regular smoking to broader societal changes, it could be that vaping and smoking play complex roles in the parallel shifts across multiple substances.

More recently, a 2024 UK study conducted an interrupted time series analysis focusing on adults to assess changes in smoking trends following rapid rises in vaping prevalence after June-2021 (due to increases in disposable e-cigarette availability in the UK).[20] Although the UK study focused on adults, whereas our study relates to adolescents, its findings and interpretation are relevant to some extent. The study found no significant changes in the rates of decline in current-smoking after June-2021 among younger adults aged 18–24 (OR for change in trend = 0.97; 0.83–1.12) and 24–44 (OR = 0.95; 0.87–1.05), yet a significant slowing in the rate of decline among adults aged 45 or older (OR = 1.20; 1.11–1.30). From this, the study authors inferred that larger increases in vaping prevalence among the two younger adult age groups may have helped prevent slowing in the rates of decline in smoking similar to the slowing observed in the oldest age group (i.e. implying vaping has a general displacement effect on smoking across all three age groups). However, this interpretation overlooks the importance of considering not only the prevalence of vaping when determining the amount of smoking attributable to—or preventable by—vaping, but also how strongly vaping is linked to smoking (i.e. the relative risk of smoking due to vaping). Importantly, the strength of this link—like the prevalence of vaping—may also vary across age groups. In this context, one of several plausible explanations could be that vaping has little or no relationship with smoking in the younger adult age groups; hence changes in vaping prevalence—regardless of magnitude—have little or no impact on their smoking rates. Conversely, if vaping is positively associated with smoking uptake among those aged 45 or older, then even a small increase in vaping prevalence could contribute to a slowing in the rate of decline in smoking. Given these considerations, future studies informally comparing changes in smoking trends across comparator groups should ensure that such groups are approximately balanced on—rather than defined by—key variables likely to be effect modifiers or potential confounders in the relationship between vaping and smoking, such as age. Alternatively, studies might consider conducting formal difference-in-differences analyses, which require the fulfillment of several assumptions regarding the comparator groups[33,34] to compare changes in smoking trends across these groups.

Although there is limited comparable prevalence data for 14–15-year-olds across culturally similar countries to New Zealand (i.e. with consistent category definitions and similar survey years), the available comparisons for recent years provide useful context. The ASH New Zealand data indicated that in 2023, 38% of 14–15-year-olds reported ever using e-cigarettes, a prevalence higher than in Australia (26% in 2022/23), the US (26% in 2021), and Canada (23% in 2021/22), but similar to England (39% in 2021).[35] Daily-vaping prevalence among 14–15-year-olds in New Zealand (10.0% in 2023) was also higher than in Australia (3.0% in 2022/23), Canada (8.0% in 2021/22), and the US (3.0% in 2021), but again comparable to England (10.0% in 2021).[35] In terms of smoking, daily-smoking prevalence among 14–15-year-olds in New Zealand (1.2% in 2023) was comparable to Canada (1.2% in 2021/22), but higher than in the USA (0.3% in 2021) and Australia (0.8% in 2022/23) (with no comparable data available for England).[36] Regular-smoking prevalence among 14–15-year-olds in New Zealand (2.8% in 2023) was similar to the US (2.8% in 2021) but lower than in Australia (3.8% in 2022/23) (with no comparable data available for Canada or England).[36] Overall, these comparisons appear to suggest that recent vaping prevalences among 14–15-year-olds in New Zealand are high compared to culturally similar countries, whereas smoking prevalences are broadly similar.

Consistent with our findings for ever-smoking and regular-smoking, previous meta-analyses of individual-level cohort studies of adolescents have found strong positive associations between vaping and ever-smoking,[12,13] and between vaping and various composite measures of more regular smoking (such as past-30-day smoking, frequent-smoking and daily-smoking combined).[13] However, it remains unclear why the rate of decline in daily-smoking among New Zealand 14–15-year-olds showed little or no change following the emergence of vaping in 2010. Unlike ever-smoking and regular-smoking, there have been no meta-analyses of individual-level studies that exclusively examined daily-smoking as an outcome, perhaps due to its rarity among adolescents (e.g. only 1.2% of the ASH New Zealand 2023 sample were daily smokers). Despite this lack of evidence on daily-smoking, the divergence in our results for ever-smoking, regular-smoking, and daily-smoking might reflect real differences in how vaping influences adolescent smoking behaviours, or at least within the New Zealand context. Although speculative, it could be that vaping encourages experimentation (ever-smoking) and somewhat more frequent smoking (regular-smoking), while still enabling dual use of e-cigarettes and tobacco. However, the time, effort, and financial costs required to sustain both vaping and daily-smoking as a dual activity may make this pattern less feasible, thereby reducing the likelihood of progression from vaping to daily-smoking.

Our study has limitations. First, although we controlled for inflation-adjusted cigarette pack prices in sensitivity analyses and addressed potential autocorrelation using two methods, producing no substantive changes to our results, other factors related to smoking may have influenced our findings. In this regard, the potential for unknown factors to confound the potential effects of vaping on smoking rates is an inherent limitation of all interrupted time series analyses such as ours, and those conducted in other countries. On the other hand, when considering potential confounding by other important (non-price-related) tobacco control policies, it is important to recognise the cumulative nature of such measures in New Zealand during the study period. Important policies implemented before 2010—such as smokefree bars and restaurants (2004) and pictorial health warnings (2008)—likely continued to exert their effects post-2010. These measures were then complemented by additional measures introduced later, including a point-of-sale display ban (2012), plain packaging with enhanced pictorial health warnings (2018), and smokefree cars legislation (2020). Importantly, none of these policies were reversed, suggesting an overall trajectory of progressive strengthening in tobacco control (although we note that important measures in the Smokefree Environments and Regulated Products Act (SERPA) were repealed outside of the study period in 2024[37]). Consequently, it seems plausible that the slowing in the rates of decline in ever- and regular-smoking that we observed might have been even more pronounced if not for the accumulation of tobacco control policies over time. Second, potential changes in the demographic composition of the samples over time, such as shifts in socioeconomic status or ethnicity, could have influenced the observed trends. However, any such shifts seem unlikely to account for the large changes in ever- and regular-smoking trends that we observed. Third, although we can find no evidence or discussion in ASH methodological reports of significant changes in survey methodology or indications of differential non-response bias that might influence comparisons over time, we cannot completely rule out the potential for such biases. Fourth, we were unable to stratify our analyses by gender, ethnicity or socioeconomic status, or patterns of dual versus single use of e-cigarettes and tobacco, because the necessary prevalence data was not available across the entire time range from 1999 to 2023. We encourage future research to extend our analysis of the ASH dataset with such stratifications as the data become available. Fifth, because our study specifically examines changes in smoking prevalence among 14–15-year-old adolescents before and after the emergence of vaping, it remains uncertain whether similar shifts have occurred in other age groups across New Zealand. Therefore, we recommend future analyses investigate potential changes in the smoking trends of other age groups using different datasets as these patterns may vary, particularly given vaping's role in supporting smoking cessation among some adults.[38]

Our analysis of ASH Year 10 Snapshot Survey data over the extended timeframe from 1999 to 2023 offers a new perspective on vaping and smoking rates among New Zealand adolescents and the possible interaction between these behaviours. Contrary to the assertions of the only other study to examine this issue in New Zealand adolescents,[16] which suggested that the decline in smoking from 2014 to 2019 might be due to the displacement of smoking by vaping, our findings suggest a more problematic scenario. The slowdown in the decline of ever- and regular-smoking rates from 2010, coinciding with the advent and subsequent rapid growth of vaping in New Zealand, suggests that among 14–15-year-old adolescents, vaping may be contributing to, rather than displacing these smoking behaviours. Moreover, if vaping is displacing daily smoking, it is barely perceivable in these data. In this context, our findings underscore the importance of effective policy approaches to curb both adolescent vaping and smoking.

Contributors
SE conceptualized the study, collected and analysed the data, and drafted the original manuscript. All authors contributed to the manuscript by reviewing and editing the draft, ensuring the integrity and accuracy of the work. SE and MD directly accessed and verified the underlying data reported in the manuscript.

Data sharing statement
All data used in the current analyses are population-level and publicly available.

Declaration of interests
MD, MFW, QL, JM and LH declare no conflicts of interest. BF has received payments to her institution from Cancer Council NSW, MRFF/NHMRC, Ian Potter Foundation, and NSW Health. She has also received consulting fees from WHO, NSW Health, Cancer Council Australia, and Sax Institute. Payment for lectures, presentations, and educational events were received from the Department of Health, Government of Hong Kong Special Administrative Region. She has been reimbursed for travel expenses related to her attendance at several conferences including the Oceania Tobacco Control Conference, Australia Public Health Association Conference, Australasian Epidemiology Association, and others. Freeman served as the Director of ASH New Zealand from May 2004 to November 2006, overseeing the delivery of the ASH Year 10 Survey, the data of which is analysed in this manuscript. She has served as an unpaid expert advisor on the Cancer Council–Tobacco Issues Committee, a paid expert member on the NHMRC Electronic Cigarettes Working Committee, an unpaid advisor on the Cancer Institute–Vaping Communications Advisory Panel, and an unpaid expert member on the CHO NSW E-cigarette expert panel. SE is supported by an Australian Government scholarship.

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Appendix A. Supplementary data
Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2025.101522.

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