Investigating the spatial and temporal variation of vape retailer provision in New Zealand: A cross-sectional and nationwide study.

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Citation:

WATERMAN, I, MAREK, L, AHURIRI-DRISCOLL, A, MOHAMMED, J, EPTON, M and HOBBS, Matthew (2024). Investigating the spatial and temporal variation of vape retailer provision in New Zealand: A cross-sectional and nationwide study. Social Science & Medicine, 349: 116848. [Article]

Social Science & Medicine 349 (2024) 116848

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Investigating the spatial and temporal variation of vape retailer provision in New Zealand: A cross-sectional and nationwide study

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ARTICLE INFO

Handling editor: Jamie Pearce

ABSTRACT

Smoking rates have decreased in Aotearoa New Zealand in recent years however, vaping has shown a dramatic upward trend especially among young people; up to 10% of young New Zealanders are now regular vapers. Importantly, the long-term health consequences for their future life are largely unknown. The accessibility of vape retailers is important, particularly in relation to the youths' daily activities and places such as schools where they spend a considerable amount of time and socialise. Despite this, we know little about the spatial patterning of vape retailers and even less of their socio-spatial patterning around schools. This ecological study utilised data from the New Zealand Specialist Vape Retailers register on nationwide vape retailer locations and combined them with whole-population sociodemographic characteristics and primary and secondary school data. We identified the prevalence of vape retailers and their spatial distribution by area-level deprivation, ethnicity and urban-rural classification by using descriptive statistics and (spatial) statistical modelling on the area-, school- and individual students-level (using disaggregated data on students). We found that almost 97% of all vape retailers are located within 1,600m (~20-min walk) and 29% within 400m (~5-min walk) of schools. Our research also identified increasing inequities by deprivation and ethnicity both for the overall population and particularly for students in the most deprived areas who experience a disproportionate presence and increase of new vape store retailers that disadvantage schools and students in these areas. This difference was particularly prominent for Pasifika populations in major urban environments.

1. Introduction

Electronic cigarette (e-cigarette) use, also known as vaping, has risen to the forefront of medical discussions across the world (Jones and Salzman, 2020) as the popularity of vaping and e-cigarettes has increased across the globe in both children and adults (Tehrani et al., 2022). Vaping devices contain batteries that heat a liquid usually containing nicotine and other toxins; some have argued that vaping is essentially a contemporary form of smoking (Reasoner et al., 2020). For instance, in a recent global systematic review and meta-regression the lifetime and current prevalence of vaping in men was 23% and in women 11% (Tehrani et al., 2022).

In New Zealand, the 2021/22 New Zealand Health Survey (NZHS) showed 27% of adults, which is an estimated 1.1 million people, had ever tried vaping. Moreover, 8.3% or an estimated 346,000 adults were now daily vapers, up from just 0.9% in 2015/16 (Ministry of Health, 2022). To contextualise this further, in NZ, there has been a dramatic reduction in daily smoking rates and the availability of vaping may be part of the reason for this reduction (Ministry of Health, 2023). However, other evidence has recently disputed this, suggesting that vaping appeared to be just as likely to have a gateway effect to smoking as it was to have a cessation effect (Mason et al., 2023). Indeed, in terms of smoking reduction, rates were reducing prior to vaping, which may mean that the attribution of vaping as the main cause of smoking reduction may be misplaced (Mason et al., 2023). For instance, in NZ, most daily vapers aged 15 years or older were ex-smokers (56%), with 22% vaping as well as smoking. However, young people aged 18–24 had the highest rate of daily vaping in 2021/22 (22.9%), up from 5.0% in 2019/20 and young people aged 15–17 years now account for 4% of all daily vapers (Ministry of Health, 2023). The latest NZHS data also

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https://doi.org/10.1016/j.socscimed.2024.116848
Received 9 August 2023; Received in revised form 18 March 2024; Accepted 27 March 2024
Available online 20 April 2024
0277-9536/

suggests significant disparities in prevalence by area-level deprivation and ethnicity for adults. Overall, 17.6% and 16.8% of Māori and Pacific adults use electronic cigarettes or a vaping device at least once a day compared to 6.3% of Asian and 7.7% of European/Other ethnicity (Ministry of Health, 2022). Those in the most deprived areas were more likely to have ever tried vaping but there was no statistically significant difference by area-level deprivation for daily use (Ministry of Health, 2022).

Perhaps of most concern, the rapid increase in the prevalence of vape use seen in 2020/21 continued in 2021/22, with the increase greatest among young people aged <25 years (Asthma and Respiratory Foundation New Zealand, 2021). A recent survey of 19,000 students in years 9–13 showed that 26% of students reported vaping and 15% reported smoking cigarettes in the past week (Asthma and Respiratory Foundation New Zealand, 2021). Moreover, nearly 20% of students were vaping daily or several times a day, and over half of those using e-cigarettes were using them more frequently and at higher nicotine doses than in previous years (Asthma and Respiratory Foundation New Zealand, 2021). These trends are a cause for significant concern. A paucity of evidence does not constitute an absence of harm (Asthma and Respiratory Foundation New Zealand, 2021).

Smoking continues to be the leading preventable cause of illness and premature death and one of the top causes of health inequalities, responsible for over eight million deaths a year globally (World Health Organization, 2020). While some have posited that vaping is less harmful than smoking or an alternative to smoking, this does not mean vaping is harmless (Jones and Salzman, 2020; Reasoner et al., 2020; World Health Organization, 2020). Vaping is attracting many people who have never smoked before to use them, including a significant proportion of children and adolescents (Asthma and Respiratory Foundation New Zealand, 2021). While the short- and long-term health effects of vaping are still to be understood, emerging preclinical and clinical studies suggest that vaping may not be harmless and may be associated with cellular alterations (Burrowes et al., 2020; Traboulsi et al., 2020). In addition, some of the compounds found in vape aerosols, which include compounds not specified by the manufacturer, are considered toxic or carcinogenic, including aldehydes, heavy metals, and tobacco-specific nitrosamines (Traboulsi et al., 2020). Some studies have posited that even short-term vaping may be associated with cellular inflammation, apoptosis, oxidative stress, and DNA damage (Lerner et al., 2016; Yogeswaran et al., 2021). A recent animal study exposing mice to vape smoke has identified a significant increase in DNA damage in several organs and has implicated vape smoke as a lung and possible bladder carcinogen (Tang et al., 2019). In addition, a new and serious respiratory condition, e-cigarette product use-associated lung injury (EVALI), has now been documented (CDC, 2020). Of concern, while evidence is not yet conclusive, some research has suggested that children and adolescents who vape can double (Yoong et al., 2021) or at least increase their subsequent risk of smoking cigarettes (Asthma and Respiratory Foundation New Zealand, 2021; CDC, 2020; Lerner et al., 2016). If such temporal associations between the introduction and increase in vaping, and the apparent increase in youth smoking is proved true, this is concerning and warrants further investigation (Asthma and Respiratory Foundation New Zealand, 2021; Yoong et al., 2021).

The causes of increased vaping are multifactorial in aetiology which may also include spatial variation in access to vape retailers. Previous reports support this, suggesting that both ease of access and social pressure amongst young people could be two key contributing factors (Asthma and Respiratory Foundation New Zealand, 2021). For instance, previous nationwide evidence in the USA has shown that vape retailers are more densely distributed in school districts with higher proportions of Asian and Black or African American populations and were closer in proximity to schools in school districts with higher proportions of Asian, Black or African American, and Hispanic or Latino populations (Venugopal et al., 2020). Understanding the spatial distribution of vape stores may help identify areas where vape store access is greatest, and thus eventually whether this is related to who may be using vape products the most (Tuson et al., 2024). However, first, identifying areas with greater access to vape stores will highlight areas where intervention is most needed (Tuson et al., 2024). Local interventions for harmful substances are not common in New Zealand, but localised approaches to restricting the availability and marketing of substances like alcohol have been shown to be effective internationally (de Vocht et al., 2020; Martineau et al., 2014). Despite this, high-quality diverse and nationwide studies investigating the spatial and temporal variation in access to vape retailers are scant. First, studies are often limited in scope, focusing on just one city or region and rarely have the power or scope to conduct a nationwide analysis. Second, any geospatial data are often static with little consideration of how temporal distributions have changed or developed over time. Third, we have a relatively poor understanding of how vape retailers cluster around schools. While we appreciate online delivery now exists, which represents another form of access we do not capture, our study aims to examine i) the spatial patterning of vape retailers (by socioeconomic deprivation and ethnicity) across New Zealand; ii) the socio-spatial patterning around schools of vape retailers and iii) the temporal distribution of vape retailers across New Zealand.

2. Methods

2.1. Study design

A cross-sectional, nationwide and geospatial study.

2.2. Data

Our study used data on vape/e-cigarette retailer location, Statistical Area 2, school location and characteristics, ethnicity, population over 15 years of age, smokers, area-level deprivation and urbanicity.

2.3. Vape/E-cigarettes retailers

We downloaded data current as of January 31, 2023 from Specialist Vape Retailers in New Zealand (n = 1120) from the Health Advisory and Regulatory Platform (HARP). First, we removed 132 records for online retailers (n = 988) and second, we removed seven duplicate values (n = 981). Addresses were geocoded using Google Maps API in R (R Core Team, 2022) and all were successfully geocoded. We then generated random numbers in Excel for 50 (approximately 5%) records and manually checked the store with that corresponding row number. Manual checks were performed by checking the geocoded location was within the correct property boundary in Google Maps. All 50 of the manually checked records had been geocoded to the correct street address and thus required no adjustment.

2.4. Statistical area 2

The statistical geography hierarchy in New Zealand has several levels, the first three of which are meshblock, statistical area 1 (SA1) and statistical area 2 (SA2) (Statistics New Zealand, 2019). The main unit of analyses conducted on area level was SA2; that aims to reflect communities interacting together socially and economically, and in populated areas, SA2s generally contain similar-sized populations (Statistics New Zealand, 2019). (A group of) SA2s often approximate a single suburb in major urban areas, while small urban areas (containing up to 5000 residents) may be represented by a single SA2 unit, and rural SA2s include the rural settlements and their surroundings (Statistics New Zealand, 2019). SA2s in city council areas generally have a population of 2000–4000 residents while SA2s in district council areas generally have a population of 1000–3000 residents. In rural areas, many SA2s have fewer than 1000 residents because they are in conservation areas or cover large areas that have sparse populations (Statistics New Zealand, 2019). Final set of SA2s contained 2141 areas after removing areas representing oceanic and water bodies, and places without any residing population.

2.5. Schools

We sourced a current list of schools across New Zealand from the New Zealand Schools, Schools Directory Builder which is updated nightly (Ministry of Education, 2023). We first extracted all records with an initial dataset of all schools containing 2564 records. First, we removed 56 records for schools with no students or those which were closed or proposed schools (n = 2508) and second, we removed 11 schools on Chatham Island, Waiheke Island, Stewart Island, Great Barrier Island resulting in a final dataset of 2499 schools. Within the school data also included the school type (i.e., composite, primary, intermediate), school decile, total number of students, and number of students by ethnicity defined as European/Pākehā, Māori, Pacific, Asian, combined Middle Eastern, Latin American and African (MELAA), Other, and International (Ministry of Education, 2023).

2.6. Area-level deprivation, ethnicity, smokers and urbanicity of the area

Area-level deprivation defined using the New Zealand Deprivation Index 2018 (NZDep2018) (Atkinson et al., 2019). NZDep2018 is an area-based socio-economic measure of deprivation available on meshblock, Statistical Area 1 (SA1) and Statistical Area 2 (SA2) levels. NZDep 2018 combines the following nine census data variables from the 2018 census that reflect eight dimensions of material and social deprivation: 1) Communication - people with no access to the internet at home; 2) Income - people aged 18–64 receiving a means tested benefit; 3) Income - people living in equivalised (methods used to control for household composition) households with income below an income threshold; 4) Employment - people aged 18–64 unemployed; 5) Qualifications - people aged 18–64 without any qualifications; 6) Owned home - people not living in own home; 7) Support - people aged <65 living in a single parent family; 8) Living space - people living in equivalised households with occupancy threshold; 9) Living condition - people living in dwellings that are always damp and/or always have mould greater than A4 size. Principal components analysis was used, as previously, to create the index (Atkinson et al., 2019). NZDep2018 is the first principal component of nine variables (Atkinson et al., 2019). Each variable is a proportion of persons and the index was created, as before, using standardised proportions, where each small area proportion was standardised in eight age/sex groups (0–17, 18–39, 40–64, 65 and over, for each sex) to the New Zealand population structure. Proportions were calculated both standardised and unstandardised as a way of checking the effect of standardisation resulting in each SA1 being assigned a deprivation score that is then collapsed into either deciles (1 = least deprived; 10 = most deprived) or quintiles (1 = least deprived and 5 = most deprived).

We sourced ethnicity data from the 2018 census defined as European, Māori, Pacific Peoples, Asian, MELAA (Middle Eastern/Latin American/African) and Other ethnicity. We presented our data as European/Other, Māori, Pacific Peoples, Asian and MELAA. The population over 15 years of age and smokers were also collected from 2018 census. The urbanicity of the area was based on the Urban Rural Indicator Statistics New Zealand (2019) that classifies areas as urban (Major, Large, Medium, Small), rural (Rural settlement, Rural other) or water (Inland, Inlet, Oceanic areas) based on population characteristics and built environment.

2.7. Geospatial and statistical analyses

First, we joined SA2 area-level deprivation data and census-based ethnicity data to SA2 polygon boundaries. We then calculated the proportion of vape retailers by quintile of area-level deprivation and by the proportion of different ethnicities across New Zealand. We visualised the access to vape retailers by both deprivation and ethnicity. Second, we calculated and repeated similar steps but for schools. After geocoding the school locations, we used a network analysis in ArcGIS Pro to find the shortest distance using the road network from school to the nearest vape retailer. We also calculated a 400m, 800m, 1200m and 1600m buffer around each school to calculate the number of vape retailers accessible within 5, 10, 15, and 20-min walk from each school. Subsequently, we combined counts of retailers and school population data to calculate a rate representing a number of vape retailers per 1000 students. Finally, as included in the supplementary materials we removed schools with 'NA' or a decile of 99 (not recorded) – 38 (n = 2466) and analysed the distance to nearest vape retailer by type of school (i.e. primary/intermediate and secondary schools). Schools Y1-10 were included in primary/intermediate and schools Y7–15 included in secondary (composite schools that included Y1–15 were counted as secondary) while other categories were for restricted entry and special schools.

We used several different regression models to quantify the potential relationship between the location of vape retailer outlets and the area characteristics of SA2 with an option for adjustments by urbanicity of the area and socioeconomic deprivation. Firstly, we used the Bayesian hierarchical model framework to account for the spatially aggregated nature of SA2 area-level data and accommodate spatial autocorrelation. Specifically, Besag-York-Mollié (BYM) logistic and negative binomial models (Besag et al., 1991) implemented within INLA (Integrated Nested Laplace Approximation) framework (Rue et al., 2009) in R-INLA package (Lindgren and Rue, 2015) were used. We used default priors as they provide a reasonable reference point due to being based on the priors commonly used in literature (Rue et al., 2009) that make them suitable when prior knowledge of the topic is limited, and complexity of models makes more subjective definition of priors impractical. Spatial random effect accounting for spatial dependence between outcomes aggregated in SA2 was modelled with a BYM2 implementation (Bakka et al., 2018) of spatial conditional autoregressive model using the first Queen's contiguity matrix to represent directly neighbouring areas. We opted for using logistic regression modelling of presence and absence of the vape store in SA2 (outcome measure) and percentages of Māori population, Pacific Peoples and MELAA populations, percentage of population over 15 years of age, percentage of smokers, deprivation quintiles and urbanicity of areas being independent variables. Besides the logistic regression we also carried out a negative binomial regression modelling counts of vape retailer outlets.

Secondly in the school focused analyses, we investigated how the distance to the nearest vape retailer outlet from a school is related to individual students. Here, we decided to apply individual-based approach due to spatial relationships among schools not being straightforward as, for example, in the case of administrative units. This meant that the definition of neighbouring schools and further construction of contiguity/neighbouring matrix was rather problematic. However, the mixed-effect model with random intercept enabled us incorporating a spatial reference using the multilevel nesting of students within the education regions of their school (regional management area) and additionally within areas by urbanicity of the school area within education regions. To obtain individual-level student data, we disaggregated school-level data by available ethnicity counts of students. This way, each student ($n = 826{,}017$) had their individual ethnicity and suitable school-level characteristics (distance to vape store, urbanicity, school, school region, and deprivation) assigned. Natural logarithm of distance was used as outcome due to the right skew of the distances (and no 0-m distances) while ethnicity of students, deprivation of SA2 where schools reside, and urbanicity of school were used as independent variables.

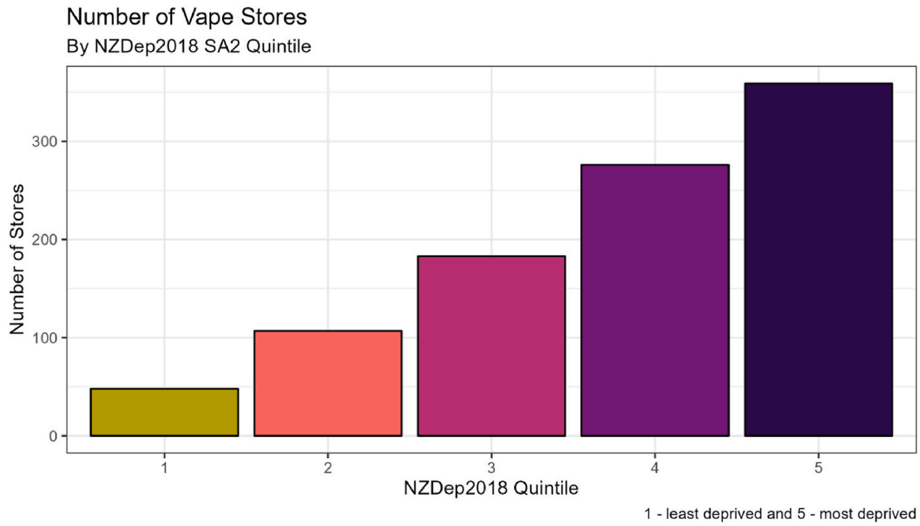

Fig. 1. The number of vape retailers by Statistical Area 2 (SA2) and area-level deprivation across New Zealand (quintile 1 = least deprived).

3. Results

3.1. Retailers by area-level deprivation and ethnicity

Fig. 1 displays the vape retailers by area-level deprivation. Our findings indicate that with increasing area-level deprivation there was an increase in the number of vape retailers. Fig. 2 shows the proportion of different ethnicities within each SA2 by the number of vape retailers highlighting SA2 areas with the greatest proportion of European and Other having the lowest number of shops. Finally, Fig. 3 shows the cumulative increase over time by area-level deprivation over time. The number of vape retailers increased over time regardless of SA2's deprivation, however we can notice steeper growth in more deprived areas. While the increase slowed down (and plateaued) in Q1 and Q2, it was still considerably in Q3 and even more so in Q4 and Q5, which suggest further widening inequities. The tables which support Figs. 1, Figs. 2 and 3 are displayed in the online supplementary materials.

3.2. Retailers around schools

Overall, 96.9% of vape retailers are located within 1600 m (20-min) and 29.1% within 400 m (5-min) of a school (Table 1). Besides that, 32.8% of schools had a vape retailer within 1 km. Fig. 4 shows the number of schools with one vape store within 1 km by area-level deprivation with Quintile 1 being the least deprived. Fewer schools in the least deprived quintile had at least one vape retailer within 1 km whereas, significantly more schools in the most deprived quintile had at least one vape retailer within 1 km of the school. Our analyses included in our supplementary materials show the same pattern when investigating the percentage of schools within each quintile with a greater percentage of schools in the most deprived quintile have a vape shop within 1 km of them.

Fig. 5 shows the road network distance (km) from schools to the nearest vape stores by area-level deprivation quintile. Clearly, our findings again show that the schools in the more deprived areas had the closest network distance to the nearest vape retailer. The statistics supporting Figs. 4 and 5 are shown in the online supplementary materials.

Fig. 6 shows the spatial distribution of vape retailers around schools in Auckland city by area-level deprivation. We used the number of stores within 400m of a school as a threshold which captures around 30% of all vape retailers and the size of circle corresponds to the number of vape retailers around the school while the colour of circle shows the school area-level deprivation quintile with darker colours representing the

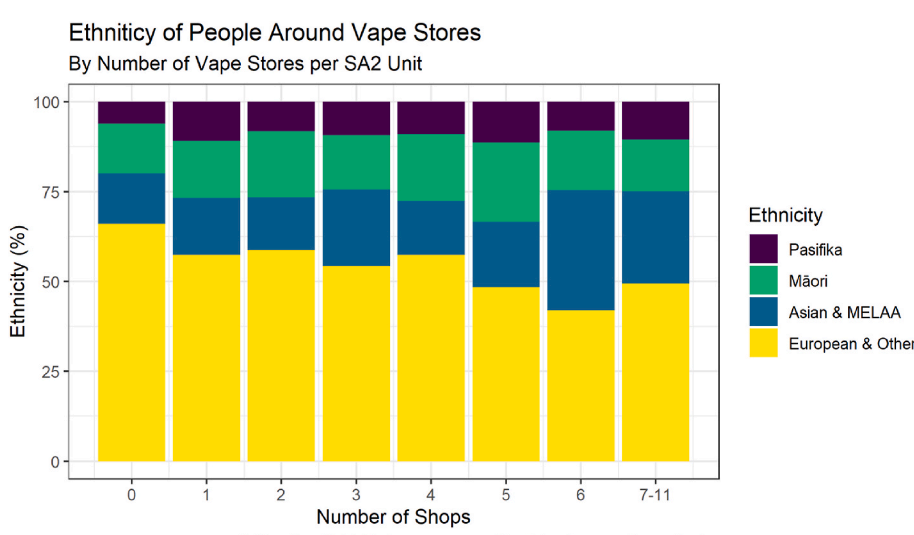

Fig. 2. The number of vape retailers per Statistical Area 2 by the proportion of different ethnicity groups across New Zealand.

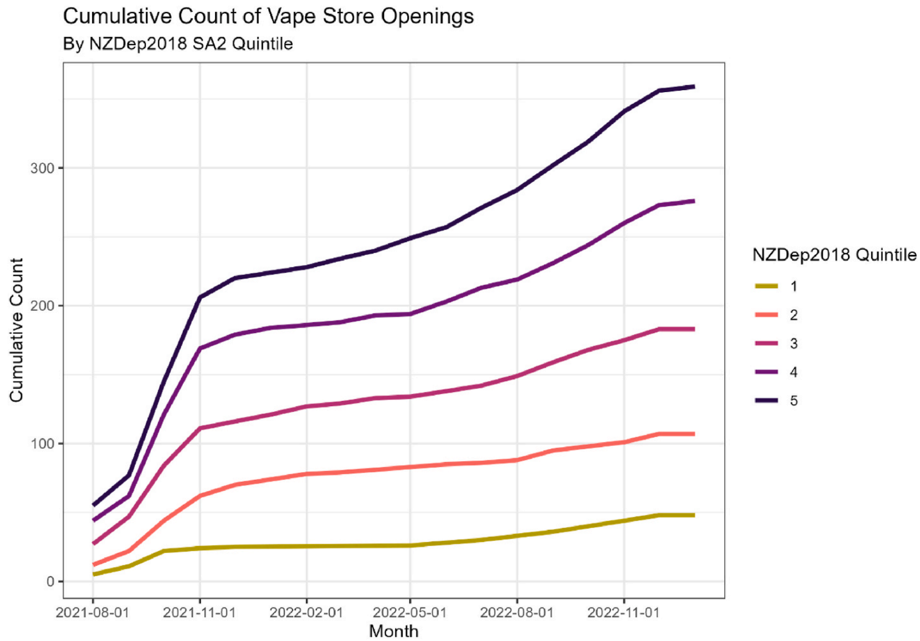

Fig. 3. The increase in vape retailers from August 2021 to January 2023 by area-level deprivation quintile across New Zealand (Quintile 1 = least deprived).

Table 1
The number and proportion of vape retailers around schools (additional summary statistics are available in Supplementary Material Tables S6–S9).

	400m	800m	1200m	1600m
Number of vape retailers	285	702	894	951
% of all vape retailers	29.05%	71.56%	91.13%	96.94%
Schools (mean count of vape retailers, [min, max])				
Q1 (least deprived) *(n = 345)*	0.03 [0, 3]	0.15 [0, 4]	0.37 [0, 6]	0.57 [0, 6]
Q2 *(n = 473)*	0.10 [0, 3]	0.33 [0, 13]	0.76 [0, 16]	1.28 [0, 27]
Q3 *(n = 501)*	0.10 [0, 3]	0.36 [0, 6]	0.65 [0, 10]	1.10 [0, 16]
Q4 *(n = 539)*	0.20 [0, 7]	0.68 [0, 15]	1.34 [0, 30]	2.16 [0, 37]
Q5 (most deprived) *(n = 636)*	0.18 [0, 4]	0.70 [0, 7]	1.35 [0, 9]	2.11 [0, 12]

School's deprivation is based on NZDep2018 of SA2 where school is located.

most deprived quintiles. Auckland (the most populated New Zealand city) was chosen as an example as there is a disproportion of vape stores (40% of all vape stores) and population (30% of NZ population), Additional maps of other cities and areas across New Zealand are included in the supplementary material. However, it is clear from Fig. 5 that there are several schools with many vape retailers within 400m and those schools are also clustered together or are often classified as deprived. We have developed an interactive map to explore the vape stores around schools which is available at https://tinyurl.com/vapestores.

3.3. *Quantifying the association between the characteristics of areas and school characteristics and vape retailer location*

As shown in Tables 2 and 3 below we estimated several models, some of which were spatial in nature, to examine the association between the characteristics of SA2 areas as well as schools and presence/absence and count of vape retailer outlets.

In Table 2 we examined the association between SA2 area-level deprivation, the proportion of ethnicity, urban/rural classification, those aged over 15 years of age as well as smoker percentage and the presence/absence of vape retailers at the SA2 level. In total, vape stores were present in 515 SA2s out of 2237. The table also includes a negative binomial model using count of vape retailers as the outcome. For SA2, the percentage of Māori (OR = 1.00 [95% CI 0.99, 1.02]), percentage of Pasifika (OR = 1.01 [0.99, 1.02]) and percentage of Asian (OR = 1.01 [0.99, 1.02]) were not related to the presence or absence of vape retailer location and effects were small. However, as MELAA percentage (OR = 1.07 [1.00, 1.13]) and percentage of population over 15 years of age (OR = 1.05 [1.03, 1.08]) increased, the odds of a vape retailer presence increased, however neither contributed to a growing count of retailers. Strong associations were noted for area-level deprivation such that more deprived areas were more likely to have a vape retailer relative to the least deprived areas. Expected associations were also detected for urban/rural classification with a decrease in odds of a vape retailer as rurality increased. Hyperparameter *Phi* suggests that there is a high proportion of variance of the random effect (that is defined as inverse of *Precision*) explained by spatial structure ($Phi_{log} = 0.72$; $Phi_{nb} = 0.66$).

In Table 3 we examined the association between school area-level deprivation, the proportion of ethnicity as well as urban/rural classification and the distance from school to the nearest retailer. We present results of multivariate linear regression model with log-transformed distance as outcome and a multilevel hierarchical model with school students nested within education regions and area by their urbanicity. Our results showed that students of other ethnicities have vape store retailer's closer relative to European students. Notably students of Pasifika origin were in general 14.8% (Exp(β) = 0.852 [0.845, 0.858]) closer to vape stores than European students and MELAA students were 6.1% closer (Exp(β) = 0.939 [0.927, 0.950]). The effect for Māori students was rather small (Exp(β) = 0.993 [0.988, 1.998]). Strong associations were again noted by area-level deprivation and expected associations were seen by urban/rural classification such that more deprived schools and more urban schools had a shorter distance to the

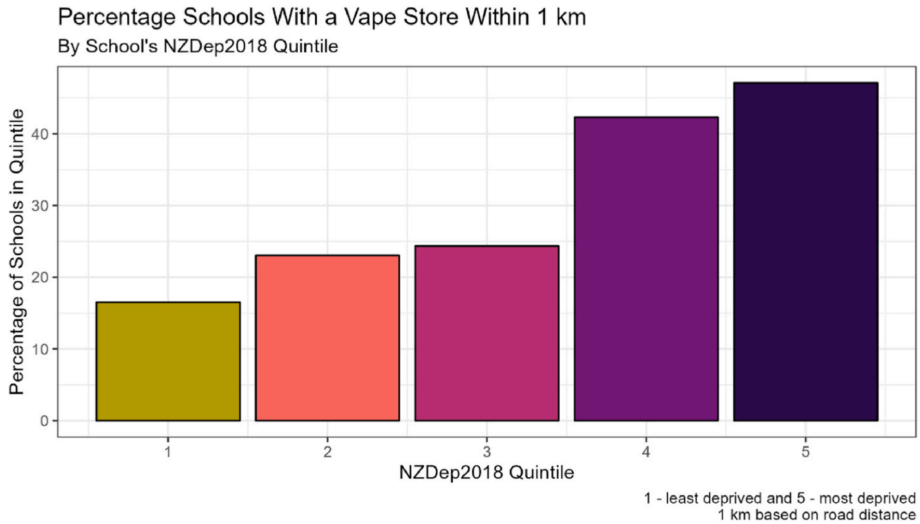

Fig. 4. Percentage of schools with one vape store within 1 km by area level deprivation (Quintile 1 = least deprived).

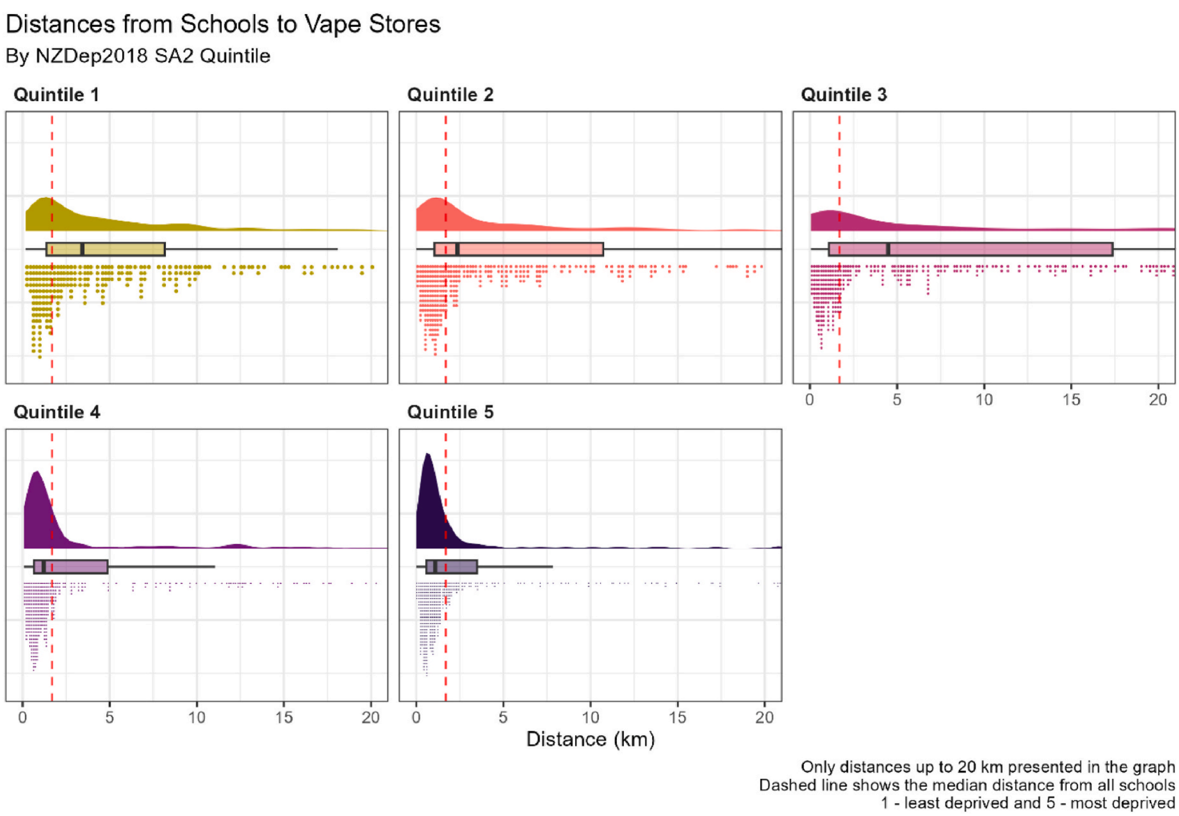

Fig. 5. Road network distance (km) from schools to the nearest vape stores by school's deprivation quintile (Quintile 1 = least deprived) based on SA2.

nearest vape retailer. However, multilevel model showed that there are strong regional and urban effects moderating these relationships. While effects for Pasifika and MELAA students stayed in place after accounting for regional and urbanicity random effects, they became weaker (Pasifika: Exp(β) = 0.954 [0.947, 0.961], MELAA: Exp(β) = 0.988 [0.977, 1.000]). Effects for Māori and Asian students switched, which seems sensible, especially for Māori students who are often more rural and effect sizes were small. The findings and effect sizes presented in both modelling approaches for schools highlight the important of higher access for Pasifika when it comes to access to vape retailers.

4. Discussion

Our study investigated the spatial patterning of vape retailers across Aotearoa New Zealand (NZ). It examined the socio-spatial patterning of vape retailers around schools and the temporal distribution of vape retailers across NZ. We have added to the literature by providing timely evidence on a new health-constraining environmental feature in our neighbourhoods which may be associated with the already well-documented health inequities in NZ (Hobbs et al., 2021; Hobbs et al., 2022; L. Marek et al., 2021a,b). Strong inequities were seen by both area-level deprivation and ethnicity with evidence of increasing inequities over time. Perhaps of most concern, 97% of all vape retailers we

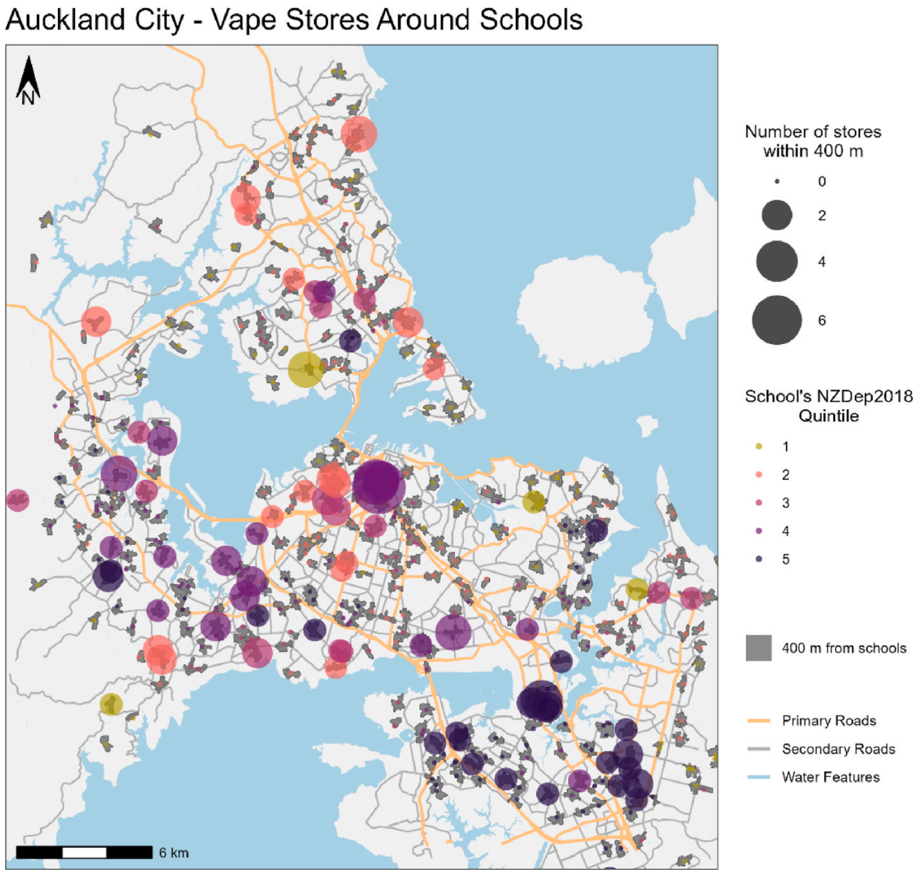

Fig. 6. The spatial distribution of vape stores around schools in Auckland city by area-level deprivation (Quintile) and the number of stores within 400m road distance of a school (size of circle = number of stores; colour of circle = school quintile). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

identified were within 1600m (20-min) of schools. Moreover, there was also a trend for vape retailers to locate near schools classified as more deprived and to some extent with a greater proportion of Māori but especially Pacific students. Some schools had up to 37 vape retailers within 1600m of schools and some of our most underserved communities had up to 7 vape retailers within 400m of the school. While there is an existing school zoning that should theoretically prevent long travels of students, considerable amount of especially more independent high school students either walk, cycle or commute on their own for longer distances. This is also the group of students with higher risk of vaping.

Our findings highlight a clear opportunity for further policy and legislation around vape retailing in NZ. An exclusion zone of at least 400m around schools which would exclude 285 or 29% of all vape retailers from close proximity to children and adolescents. However, it is important to acknowledge that 400m exclusion zones would be different depending on the urban form of the city or area with a 400m exclusion zone in Auckland providing a very different meaning to a 400m exclusion zone to Christchurch for instance. To address this, our geospatial maps show which areas have the most vape retailers and the schools which have the most vape retailers within 400m which could be used to inform decision-making.

Our nationwide study showed strong disparities by both area-level deprivation and ethnicity with a greater number of vape retailers in the more deprived areas and in places that have the highest proportion of Māori, Pacific and Asian individuals. Our findings highlight yet another form of inequity, in this case, inequitable access to vape retailing (Hobbs et al., 2019; Pearce et al., 2011; Richardson et al., 2010). By far the least number of vape retailers were located in the least deprived areas of NZ. Our findings support other previous research which has shown that a higher concentration of exclusive smoke and vaping shops were located in areas with a higher concentration of ethnic minorities and lower income and lower status neighbourhoods (Ashing et al., 2022; Dai et al., 2017). The findings of this study with respect to the spatial distribution of vape retailers, is consistent with international and local studies which have found higher densities of other unhealthy environmental exposures in highly deprived areas (Campbell et al., 2021 L Marek et al., 2021a,b; Marek et al., 2023; Wiki et al., 2018). In NZ, the socially stratified distribution of other unhealthy environmental exposures such as alcohol retailers and electronic gaming machines has been linked to increased levels of gambling and alcohol-related harm in socioeconomically deprived populations (M. Cameron et al., 2016a,b; M. P. Cameron et al., 2016a,b;Ward et al., 2020). For instance, our study showed that there were several schools with many vape retailers within 400m and those schools are also clustered together or are often classified as deprived. Our findings also extend evidence (Hobbs and Atlas, 2019) to show that not only do more deprived neighbourhoods have more vape retailers but that these inequities have increased over time with more deprived neighbourhoods seeing a notable increase in the number of vape retailers over time while the least deprived areas remain relatively static.

Perhaps of most concern in this study, we found similar if not stronger disparities by schools by metrics of both area-level deprivation and ethnicity; particularly in Auckland. Overall, schools in the least deprived areas had the greatest road network distance to the nearest vape retailer and they also had the lowest count of vape retailers within close proximity to the school. For instance, when examined by area-level deprivation, there were fewer schools in the least deprived quintile with a vape store within 1 km compared to a greater number in the most deprived quintile with a vape store within 1 km. Auckland accounted for an estimated 40% of vaping outlets. This patterning is neither accidental

Table 2
Examining the association between the presence/absence of vape retailers in the SA2 area and sociodemographic and socioeconomic characteristics of the SA2 (Bayesian spatial model).

	Logistic		Negative binomial	
	OR[a]	95% CrI[a]	IRR[a]	95% CrI[a]
Ethnicity				
Māori(%)	1.00	0.99, 1.02	1.01	1.00, 1.02
Asian (%)	1.01	0.99, 1.02	**1.01**	**1.00, 1.02**
MELAA (%)	**1.07**	**1.00, 1.13**	1.03	0.96, 1.08
Pasifika (%)	1.01	0.99, 1.02	1.01	1.00, 1.02
Other sociodemographic				
15+ (%)	**1.05**	**1.03, 1.08**	**1.09**	**1.07, 1.12**
Smoker (%)	1.03	0.99, 1.06	1.03	1.00, 1.06
NZDep2018 (Quintile)				
1 (least deprived)	Reference group			
2	**1.55**	**1.01, 2.39**	**1.61**	**1.09, 2.38**
3	**2.46**	**1.59, 3.86**	**2.36**	**1.59, 3.52**
4	**3.91**	**2.44, 6.37**	**3.42**	**2.26, 5.24**
5 (most deprived)	**5.86**	**3.22, 10.86**	**5.13**	**3.07, 8.64**
Urban/Rural				
Major urban area	Reference group			
Large urban area	0.83	0.54, 1.27	0.84	0.60, 1.17
Medium urban area	0.76	0.48, 1.21	0.75	0.52, 1.08
Small urban area	0.86	0.57, 1.32	0.87	0.62, 1.22
Rural Settlement	**0.19**	**0.09, 0.37**	**0.15**	**0.07, 0.28**
Rural other	**0.04**	**0.00, 0.24**	**0.03**	**0.00, 0.18**
Model hyperparameters				
Precision (for spatial ID)	5.85	1.67, 17.93	22.74	17.43, 69.30
Phi (for spatial ID)	0.72	0.24, 0.99	0.66	0.17, 0.98
DIC	2094.24		3355.82	
WAIC	2094.24		3355.26	
Marginal log-likelihood	−945.49		−1583.99	
n	*2141*		*2141*	

[a] OR = mean Odds Ratio, CrI = Credibility Interval, IRR = mean Incidence Rate Ratio.

nor random. It has been suggested, for instance, that the placement of fast-food outlets in areas of lower socioeconomic status by transnational companies is strategic (Anaf et al., 2017). There may be greater demand, less civic resistance to new developments, and lower land use costs for business in more deprived areas, and thereby, maximum profit (Fraser et al., 2010; Wiki et al., 2018). What this means is that, in seeking to address the increased accessibility of unhealthy products such as e-cigarettes, and the resultant harms, we must consider commercial and private sector forces, the so-called commercial determinants of health (Maani et al., 2022). Importantly, while our study can say where vaping retailers are locating it cannot say why. It is important to note that it is unlikely that vape retailers are targeting schools in low deciles for instance and is more likely due to other unknown factors or confounder such as cost of land in low decile areas. However, it remains an important distinction to make in that our study is only able to say what and where things are occurring but not why and how without speculating and further research is needed to confirm this.

While we acknowledge that smoking rates may be higher in the more deprived areas of NZ, as the percentage of people vaping increases, it will be necessary for countries to have more control over the consumption and distribution of vape products, as well as to formulate laws prohibiting the consumption of vaping products in public places for instance. Any regulatory changes for vape advertising and promotion should at least discourage the use of and reduce the exposure of young people to vape products. The New Zealand government has recently taken steps to regulate the sale and marketing of vape products. With the aim of reducing their use among young people it has ensured that vape products are now subject to the same age restrictions as traditional cigarettes, and it is illegal to sell them to anyone under the age of 18 (Te Whatu Ora - Health New Zealand, 2023). The Smokefree Environments and Regulated Products (Vaping) Amendment Act 2020 (the Amendment Act) commenced on November 11, 2020 requires all workplaces, including restaurants and bars to be Smokefree and Vapefree (Te Whatu Ora - Health New Zealand, 2023). However, our results go further to

Table 3
Factors associated with students distance from school to the nearest vape retailer.

	Linear regression		Multilevel model	
	Exp(β) (95% CI[a])	p-value	**Exp(β) (95% CI[a])**	p-value
Ethnicity				
European	Reference group			
Māori	**0.993 (0.988, 0.998)**	**0.010**	**1.021 (1.016, 1.027)**	**<0.001**
Pacific	**0.852 (0.845, 0.858)**	**<0.001**	**0.954 (0.947, 0.961)**	**<0.001**
Asian	**0.925 (0.920, 0.931)**	**<0.001**	**1.012 (1.006, 1.018)**	**<0.001**
MELAA	**0.939 (0.927, 0.950)**	**<0.001**	**0.988 (0.977, 1.000)**	**0.047**
NZDep 2018 (Quintile)				
1 (least deprived)	Reference group			
2	**0.753 (0.748, 0.758)**	**<0.001**	**0.729 (0.724, 0.733)**	**<0.001**
3	**0.683 (0.678, 0.688)**	**<0.001**	**0.659 (0.654, 0.663)**	**<0.001**
4	**0.539 (0.535, 0.543)**	**<0.001**	**0.522 (0.519, 0.526)**	**<0.001**
5 (most deprived)	**0.508 (0.505, 0.512)**	**<0.001**	**0.516 (0.512, 0.52)**	**<0.001**
Rural/Urban				
Major urban area	Reference group			
Large urban area	**1.241 (1.234, 1.249)**	**<0.001**	1.102 (0.726, 1.673)	0.647
Medium urban area	**1.105 (1.097, 1.113)**	**<0.001**	0.939 (0.628, 1.404)	0.760
Small urban area	**2.284 (2.268, 2.300)**	**<0.001**	**1.824 (1.229, 2.709)**	**0.003**
Rural settlement	**11.492 (11.359, 11.626)**	**<0.001**	**8.816 (5.937, 13.092)**	**<0.001**
Rural other	**9.391 (9.311, 9.473)**	**<0.001**	**8.01 (5.395, 11.893)**	**<0.001**
Random effects	–		Variance	
Education region	–		0.028	
Education region: Rural/Urban	–		0.149	
Residual	–		0.813	
Adjusted R^2/pseudo-R^2	0.397		0.446	
Log-likelihood	−1,123,541		−1,086,668	
AIC	2,247,112		2,173,370	
BIC	2,247,287		2,173,567	
n	*825,980*		*825,980*	
Incomplete records	*37*		*37*	

[a] CI = Confidence Interval.

highlight the relevance of our results to inform vape product retailing policy and legislative changes. This is particularly concerning as emerging evidence has suggested that vaping may be associated with depression, attention deficit hyperactivity disorder (ADHD), and conduct disorder in adolescents as well as respiratory disorder among adults including both asthma and chronic pulmonary disorder (Dwyer et al., 2009; Wills et al., 2019). In addition, nicotine exposure has been shown to adversely affect brain development in animal models and increases the risk of problems with learning and memory (Goriounova and Mansvelder, 2012). Moreover, as vape products have not been widely available the illnesses caused by exposure to toxic substances may not show up for several decades as the impacts of long-term use are still unknown. This is especially concerning as a recent study showed that the majority (79.9%) of student's young people in NZ who reported vaping within the last week in our survey, also reported using ENDS with very high (>24 mg) nicotine doses (Asthma and Respiratory Foundation New Zealand, 2021). While vaping may be posited as an effective smoking cessation tool other consequences now need to be taken into consideration.

Our study and its findings should be interpreted considering both our study strengths and limitations. First, this study employed a cross-sectional design examining a highly dynamic retail sector that is likely to change over time. Despite this, we do believe that we did capture some of this change over time with our temporal analyses however, our findings may be subject to the Modifiable Area Unit Problem. Second, we use a recognised nationwide registry of vape retailers; however, the temporal resolution of our register data is slightly mismatched to the school and area-level deprivation data which may introduce unknown bias. Despite this, we do add to evidence by using the network distance from vape retailers to schools as well as count which captures availability not only proximity. We only capture one aspect of accessibility and availability. Increasingly, online delivery services can deliver vape and other goods which are not captured within our dataset. This is important as a recent study showed that among NZ teenagers who vaped, just over half obtained their vape products from friends or peers and 15.4% each from a family member, or online and none from vape shops or convenience stores (Nicolaou et al., 2022). However, online delivery is only one component of this complex area with other influences like vape shop signage or frontage also important influences. Therefore, while current restrictions on e-cigarette access that are focused on vape shops are necessary as part of a comprehensive strategy, this will not totally prevent access to e-cigarettes among young people aged under 18 years (Nicolaou et al., 2022) even though another recent NZ study suggested the most common source of supply for students was from dairies/convenience stores (Asthma and Respiratory Foundation New Zealand, 2021). In addition, there is an existing temporal mismatch between 2018 Census data, and school and vaping data that were collected in 2023. However, 2018 Census was still the best publicly available resource of population-level data in time of the analysis. Furthermore, we acknowledge that the evidence surrounding vape use is emerging and previous evidence has suggested vape were useful as a smoking cessation tool however, with the long-term effects of vape use unknown combined with the high percentage of young people vaping this is enough to warrant concern and further investigation. Finally, we need to remember that our ethnicity groups (i.e. Pacific and Asian) are not homogeneous and there will be variation within those groupings in terms of access.

5. Conclusion

We use robust nationwide evidence to provide a novel perspective on the nationwide vaping retail landscape. Our study adds to growing evidence that informs policy efforts, such as local ordinances restricting the promotion and sale of vaping products close to schools (Tuson et al., 2024; Venugopal et al., 2020). While some research has suggested that most vape users in New Zealand, including youth, are not current smokers or ex-smokers, the recent evidence has shown that vape products are highly addictive and can possibly serve as a gateway to the use of traditional cigarettes or double use of both vape and tobacco products, particularly among young people (Mason et al., 2023). Indeed, it is entirely plausible that we may see an increase in youth smoking rates because of the vaping rates in young people. Therefore, it is of concern that we see such inequities in access across New Zealand; a contemporary form of inequity that needs tackling. Our study can be used alongside others in this field from which future research efforts can now build on to enable policy to do more to protect young people.

Ethics approval

No full ethics approval required as out of scope all data were publicly available secondary data.

Funding

This project was funded by HRC Emerging Researcher Grant (22/528).

CRediT authorship contribution statement

I. Waterman: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation. **L. Marek:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Formal analysis, Data curation, Conceptualization. **A. Ahuriri-Driscoll:** Writing – review & editing, Writing – original draft, Conceptualization. **J. Mohammed:** Writing – review & editing, Writing – original draft, Conceptualization. **M. Epton:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **M. Hobbs:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

None to declare.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2024.116848.

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