The environment an adult resides within is associated with their health behaviours, mental and physical health outcomes: a nationwide geospatial study

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Abstract

Background:
The determinants of health behaviours and health outcomes are multifaceted and the surrounding environment is increasingly considered as an important influence. This pre-registered study investigated the association between the geospatial environment people live within and their health behaviours as well as mental and physical health outcomes.

Method:
We used the newly developed Healthy Location Index (HLI) to identify health-promoting and health-constraining environmental features that people live around. We then used Time 10 (2018) data from the New Zealand Attitudes and Values Survey (NZAVS; *N* = 47,951), a national probability sample of New Zealand adults, to gauge mental health outcomes including depression, anxiety and psychological distress, physical health outcomes including BMI and type II diabetes, and health behaviours such as tobacco smoking and vaping. Linear and logistic multilevel mixed effect regression models with random intercepts of individuals nested within geographical areas (meshblocks) were employed.

Results:
The presence of health-constraining environmental features were adversely associated with self-reported mental health outcomes of depression, anxiety, and psychological distress, physical health outcomes of BMI and type II diabetes, and negative health behaviours of tobacco smoking and vaping. By contrast, health-promoting environmental features were uniquely associated with physical health outcomes of BMI and type II diabetes.

Conclusion:
The current study advances research on environmental determinants of health behaviours by demonstrating that close proximity to health-constraining environmental features is related to a number of self-reported physical and mental health outcomes or behaviours. We provide some evidence to support the notion that preventive population-health interventions should be sought.

Highlights

- The environmental features of places influence people's mental and physical health.
- We relate objective environmental good/bad metrics to national data.
- Some health-promoting environmental features linked to better health outcomes.
- Certain health-constraining environmental features linked to poorer health outcomes.
- Results further support the validity of the New Zealand Healthy Location Index.

1. Introduction

Globally, mental and physical health conditions cause a significant burden to both individuals and society (1-3). In 2016, mental and addictive disorders were estimated to affect more than 1 billion individuals worldwide causing 7% of all the global burden of disease as measured in disability-adjusted life years (4, 5). The prevalence of adverse physical health conditions such as obesity and type II diabetes is also concerning (6). For instance, high body mass index has increased over time and recent estimates suggested high body mass index caused 2.4 million deaths in 2017; a substantial increase since 1990 (6, 7). New Zealand is part of the global pattern for an increasing prevalence of physical and mental health conditions. To illustrate, there have been notable increases in the prevalence of adults experiencing psychological distress, with around 7% of adults reporting psychological distress in the past four weeks in 2019/20, up from around 4% in 2011/12 (8). Moreover, depression was estimated to affect around 17% or 660,000 adults in 2019/20 (8), and anxiety disorders in the adult population have increased from around 6% in 2011/12 to around 11% in 2019/20 (2). Furthermore, around a third of all New Zealand adults are now living with obesity, and 6% have type II diabetes (6, 8).

Mental and physical health conditions do not emerge in isolation. Individuals are nested within socio-environmental contexts that have detrimental or beneficial effects on individuals' mental and physical health (3, 9). Indeed there is robust evidence regarding the impact of environmental contexts in the way people feel, think, and act (10), especially regarding the restorative as well as harmful impacts of environmental features on health outcomes (11-13). In particular, two prominent theories articulate the restorative benefits of natural environments (for reviews, see (14, 15)). According to stress recovery theory (16-18), every day, non-extreme environments can have marked influences on stress recovery. Another related theoretical perspective, attention restoration theory, articulates the psychological benefits of the natural environment regarding recovery of the capacity to focus attention (19-21). Laboratory and field studies support predictions from these theories that visual exposure to natural environments supports stress reduction by fostering pleasant emotional states while blocking negative emotional and cognitive states, and by increasing parasympathetic activity (22, 23), as well as that natural environments can aid in the recovery of directed attention (23-25).

There is a plethora of evidence which has attempted to relate environmental influences to health behaviour and health outcomes (26, 27). A systematic review concluded that the environment has measurable associations with psychological distress (28). However, most research was cross-sectional and did not always investigate a comprehensive range of exposures or outcomes. A recent meta-analysis of cohort studies found evidence of an inverse association between surrounding greenness and all-cause mortality (29) and another study found that moving to greener urban areas was related to mental health improvements (30). Despite this, different aspects of the neighbourhood environment such as fast-food outlets and physical activity facilities may act together and as such accounting for their co-location is an important consideration (31-33). A recent study by Mason et al. (2020) (33) used cross-sectional data from UK Biobank for 345,269 urban-dwelling adults aged 40-69 and demonstrated that the potential benefits of formal PA facilities in terms of obesity risk may be undermined by an unhealthy food environment close to home. The relationship between PA facilities and BMI was attenuated among those with more takeaway stores near home, compared with people with none. There is therefore a need to better understand how the geospatial proximity and availability of several environmental features such as greenspaces or food outlets relate to a range of health behaviours and health outcomes (34-36). Moreover, the Access to Healthy Assets and Hazards (AHAH) index of 14 health-related features of neighbourhoods in the UK demonstrated that the most health-promoting areas of Great Britain were typically smaller towns and suburban areas on the outskirts of cities which had access to health services and green spaces, but were further away from polluted environments or retail services that were potentially unhealthy (37). While such measures are useful to capture the multifaceted nature of environments, evidence investigating the resulting associations with both mental and physical health are only just emerging.

Research is required to quantify the links between combined measures of the environment, health behaviours, and both mental and physical health outcomes. Capturing several aspects of the environment at once is said to better reflect the multifaceted influence of the environment on behaviour and health (31, 37, 38). However, seldom does research investigate the effect of the same environmental index on health behaviours including novel behaviours like vaping as well as mental and

physical health outcomes such as psychological distress and type II diabetes. The current pre-registered study aimed to examine the association between how healthy an environment was, represented by novel and rigorous data drawn from the healthy living index (39), and the association with odds of several health behaviours (e.g., vaping) mental health outcomes (e.g., depression, anxiety and psychological distress) and other health outcomes (e.g., body mass index, type II diabetes, alcohol behaviour disorder, gambling behaviour disorder).

This study aims to combine data from two independent sources, the HLI that measures the extent to which an area is health promoting versus health constraining, and a nationally representative survey of adults living across these different regions, to test our predictions. To provide a comprehensive examination of the associations between environmental contextual factors and health outcomes, we included all available individual-level mental and physical health measures available in the survey. Instead of specifying predictions for each specific outcome, we articulated the broad pre-registered hypothesise that residing within an unhealthy environment will be associated with greater odds of engaging in unhealthy behaviours, and poorer mental and physical health outcomes. This prediction is based on past empirical evidence regarding the associations between urban and natural environments and both psychological and physical health (for reviews, see (26-28, 40)).

2. Methods

2.1 New Zealand Attitude and Values Survey sampling procedure

For testing our pre-registered predictions examining the cross-sectional associations between the HLI and physical and mental health outcomes, we used data from Time 10 (2018) of the New Zealand Attitudes and Values Study (NZAVS) which is a nationwide panel study that began in 2009 based on a random sample of the Electoral Roll. The New Zealand Electoral Roll is publicly available for scientific research and includes all citizens and permanent residents over 18 years of age who are eligible to vote, regardless of whether they choose to vote, barring people who had their contact details removed due to specific case-by-case concerns about privacy. In the present study, we used the Time 10 (2018) data of the NZAVS which contained responses from 47,951 adults. Complete details about the NZAVS sampling procedure are provided in elsewhere (41). The NZAVS is reviewed every three years by the University of Auckland Human Participants Ethics Committee. The most recent ethics approval was on 26/05/2021 for three years (Reference Number UAHPEC22576).

2.2 Outcome and control measures

Our pre-registration (see https://osf.io/st6bn/) included eight health behaviours and outcomes including three for mental health (i.e., depression, anxiety, and psychological distress) and four for physical health behaviours and outcomes (i.e., body mass index, alcohol disorders, cigarette smoking and vaping, and gambling behaviour disorders). These specific variables were selected because they captured all the mental and physical health behaviours and outcomes available in the dataset. As described below, type II diabetes was included in complementary analysis to confirm the observed findings regarding body mass index. Diagnosis with depression, an anxiety disorder, or diabetes, were assessed by asking participants if they had been diagnosed with a series of different health conditions, by a doctor, in the last five years (42). Psychological distress was measured using the Kessler6 (43). The Kessler6 scale asks participants to rate on scales from 0-4 how in the last 30 days they experienced six emotional states, such as feeling worthless, or so depressed that nothing could cheer them up (scores were averaged, and thus ranged from 0 [low distress] to 4 [high distress]). In addition to the main outcome variables, our models adjusted for age, gender, ethnicity, education level, and physical activity/exercise.

2.3 Geospatial exposures: the Healthy Location Index

For the purpose of this study, the context or environment is defined as the geospatial proximity of environmental features which can include health-promoting aspects such as greenspaces, physical activity facilities and fruit and vegetable stores, as well as health-constraining features such as alcohol outlets, fast-food, dairy and convenience stores. Data on the Healthy Location Index (HLI) have been described previously in detail (39). Briefly, data were sourced from ten environmental variables which

included five health-promoting features (e.g., supermarkets, fruit and vegetables stores, physical activity facilities, green spaces and blue spaces i.e. rivers, lakes and ponds) and five health-constraining environmental features (e.g., fast-food, takeaway, dairy and convenience, alcohol outlets and gambling venues). These were sourced from Territorial Authorities, Ministry for Primary Industries, Ministry for the Environment, Land Information New Zealand, Alcohol Regulatory and Licensing Authority, Zenbu, and Department of Internal Affairs for the 2015–2018 period. The HLI builds on recent developments in evidence which has moved towards acknowledging the multiple influences of the environment on health behaviours and health outcomes (31, 32, 37, 44).

For the analysis of accessibility, meshblock administrative units were used, which are the smallest geographic units for which statistical data is reported by Statistics New Zealand with an ideal size range of 30–60 dwellings (45). For all features other than blue and green spaces distance from the 2018 population-weighted centroid of the 2018 meshblock were calculated via road network (46) using ArcGIS Pro v2.4 (47). For blue and green spaces, median proximity from any place in the meshblock to each blue and green space (Euclidean distance) based on the 50 × 50 m grid was calculated for each meshblock instead of the closest facility.

As described previously (8), to construct indices of environmental 'goods' and 'bads', each meshblock was ranked based on its access to the closest individual environmental features in all domains except green- and blue spaces (values from 1 to 52,923, one being the closest to the feature). The proximity measure was used for ranking of green and blue spaces. Then, ranks for health-promoting 'goods' (green spaces, blue spaces, physical activity facilities, supermarkets and fruit and vegetable outlets) and health-constraining 'bads' (fast-food outlets, takeaway outlets, dairy outlets and convenience stores, alcohol outlets, and gaming venues) were summed. These scores were ranked again to get information about combined access to environmental 'goods' and 'bads'. As the final step, deciles were assigned to ranks. The resulting index is between 1 and 10. Decile 1 was defined as the best accessibility while Decile 10 was defined as the worst accessibility. For 'goods' this meant that the best accessibility was healthy, for instance with greater access to 'goods' such as green spaces. For 'bads', greater accessibility was a bad thing as this means greater accessibility to health-constraining environmental factors such as alcohol outlets (Figure 1).

INSERT FIGURE 1 HERE

To combine the environmental data in this study we first split environmental 'goods' and 'bads' deciles into three categories: category one was the best accessibility (deciles 1–3), category two was defined as mid accessibility (deciles 4–7), and category three was defined as the worst accessibility (deciles 8–10) of health-promoting and health-constraining environments. For environmental 'goods', category one is the most health-promoting environment while category three is the least health-promoting environment. For environmental 'bads', category one was the most health-constraining while category three was the least health-constraining. Data were then combined into nine possible combinations of environmental 'goods' and 'bads' to develop a healthy location index for the whole of New Zealand at the meshblock scale. Areas with a 3-1 score would have the most health-constraining features and least health-promoting, while areas with a 1-3 score would have the most health-promoting and least health-constraining features.

INSERT FIGURE 2 HERE

2.6 Statistical analyses

HLI data about the characteristics of each meshblock (using 2018 MBU codes) were integrated into the NZAVS. Descriptive statistics were first explored by investigating the characteristics of the study sample; i.e., n (%) or mean (standard deviation). Second, we stratified the sample by the nine HLI categories and examined the frequency or mean values of vaping, smoking tobacco, depression, anxiety, psychological distress, BMI and type II diabetes. Finally, we then used linear and logistic multilevel mixed effect regression models with random intercepts with individuals nested within meshblocks to investigate the associations between the nine HLI categories and the health behaviours and outcomes. We extended the pre-registered analyses to then use the deciles of exposure to health-constraining and health-promoting environmental features to investigate if it were particular components of the HLI that were driving some of the associations seen with the health behaviours and health outcomes.

3. Results

3.1 Descriptive statistics

Table 1 shows the study sample characteristics. Using Time 10 (2018) NZAVS data, the sample was majority female (62.8%, n=30,022) with a mean age of 49 years of age. This gender imbalance is a known bias in the NZAVS and other public surveys, with women generally being more likely to participate in surveys than men (41). Overall, 83% of the sample were classified as European/other, 5.2% as Asian, 1.9% as Pacific and finally 10.1% were Māori. Education was coded using the New Zealand Qualifications Authority scheme (M=5.30, SD= 2.74) which ranged from 0 (none) to 10 (doctoral degree or equivalent). For health behaviours, around 3% currently vaped or used e-cigarettes, while 5% had ever vaped. Approximately 7% currently smoke tobacco cigarettes, and 37% had reported ever smoking tobacco cigarettes. For health outcomes, 14.5% of the sample reported diagnosis of depression, 10.2% reported diagnosis of an anxiety disorder, and 3.6% type II diabetes. Finally, mean BMI was 26.22 (SD=8.08) and psychological distress had an average score of 0.89 on the 0-4 scale (SD=0.69). Note that the NZAVS estimates of alcohol usage are fairly consistent with those obtained by the Ministry of Health with the New Zealand Health Survey (48). However, very few adults in the NZAVS sample reported formal diagnosis with a gambling or alcohol addiction disorder (ns = 1 and 33). As so few individuals reported having an alcohol or gambling disorder these outcomes were not analysed further.

INSERT TABLE 1 HERE

Table 2 shows the identified prevalence of the outcome HLI category. Overall, there was a higher prevalence for each adverse health outcome and health behaviour as the HLI category became more health-constraining and less health-promoting. For example, the general pattern showed that the highest prevalence of depression, anxiety, type II diabetes, psychological distress, high BMI, current smoking and current vaping was in those HLI categories that were health-constraining while health-promoting environments had the lower prevalence. There were some exceptions; however, these exceptions only occurred when the corresponding number of individuals included was small. The frequency of individuals at Time 10 (2018) NZAVS data who resided within each HLI category is shown in supplementary materials. Fewer individuals resided within each of the extreme categories of the HLI with only 1.2% (n=568) of the sample residing within the most health-constraining HLI (3-1) and 1.3% (n=627) residing within the most health-promoting (1-3). In contrast, 17.5% (n=8,321) resided within 3-3, 23.3% (n=11,080) resided within 2-2 and 16.7% (n=7,933) resided within 1-1.

3.2 Associations between HLI, health behaviours and health outcomes

Table 3 shows the adjusted odds ratios (AOR) of HLI category on health behaviours and health outcomes. Supporting our pre-registered predictions, after controlling for age, gender, ethnicity, socioeconomic status and exercise, health-promoting environments were often beneficial, while health-constraining were often adverse for health behaviours and outcomes.

3.2.3 Health behaviours

There were several associations between the HLI and the health behaviours of vaping and smoking tobacco. Residing in a health-constraining environment was related to an increased odds of vaping (3-1: AOR=1.806 [1.149, 2.837]) as well as neither (1-1: AOR=1.289 [1.068, 1.556]). However, there were no associations between vaping and health-promoting environments. For tobacco, residing in a certain health-promoting environment was related to reduced odds of smoking (2-3: AOR=0.822 [0.688, 0.982]). Only some neither (1-1: AOR=1.151 [1.015, 1.305]) and health-constraining environments (2-1: AOR= 1.161 [1.011, 1.333]) were related to increased odds of smoking tobacco.

3.2.2 Mental health

Residing within some health-promoting environments (2-3: AOR= 0.855 [0.758, 0.965]) and neither (3-3: AOR=0.766 [0.699, 0.840]) was related to a lower odds of depression. Residing in neither was related to increased odds of depression (1-1: AOR=1.165 [1.069, 1.270]). For anxiety, residing within the health-promoting environments (2-3: AOR=0.850 [0.739, 0.977]) and neither (3-3: AOR=0.771 [0.693,

0.857]) was related to a lower odds of anxiety. However, there was no association between anxiety and any of the health-constraining environments. For psychological distress, some of the health-promoting environments (2-3: b= -0.031 [-0.056, -0.006]) and neither (3-3: b= -0.046 [-0.065, -0.026]) were related to decreased psychological distress. Most of the health-constraining environments (2-1: b= 0.052 [0.031, 0.074], 3-1: b= 0.062 [0.005, 0.119])) and neither (1-1: b= 0.043 [0.023, 0.062]) were related to increased odds of psychological distress.

3.2.3 Physical health outcomes

There was a lower odds of type II diabetes for those residing in health-promoting environments (2-3: AOR=0.673 [0.499, 0.806], 1-2: AOR= 0.833 [0.696, 0.998]) and neither (3-3: AOR=0.651 [0.544, 0.779]). There was no association for health-constraining environmental classifications. Similarly, for BMI, most of the health-promoting environments (2-3: b= -0.452 [-0.745, -0.159], 1-2: b= -0.303 [-0.543, -0.063]) and neither (3-3: b= -0.328 [-0.552, -0.105], 1-1: b= -0.242 [-0.468, -0.016]) were associated with lower BMI but there was no association for health-constraining. As noted above, and in contrast to the initial pre-registration, alcohol and gambling disorders were not included due to the small number of individuals reporting a gambling or alcohol disorder.

3.3 Associations between specific health-constraining and health-promoting features and health behaviours and health outcomes

Table 4 shows the odds of health behaviours and outcomes when health-constraining and health-promoting features were modelled separately as deciles of exposure (i.e., for decile 10 for health-constraining this had the least health-constraining while for decile 10 for health-constraining this had the least health-promoting features).

3.3.1 Health behaviours

For vaping, close proximity to health-constraining features were strongly related to the odds of vaping such that those individuals residing within the areas that had less proximity to health-constraining features had the lower odds of vaping (compared to D1, D8: AOR=0.605 0.452, 0.807] D9: AOR=0.633 [0.459, 0.827] D10: AOR=0.723 [0.495, 1.054]). In contrast, there was no association between vaping and health-promoting features (compared to D1, D8: AOR=0.871 [0.650, 1.166], D9: AOR=0.904 [0.655, 1.248], D10: AOR=0.845 [0.581, 1.227]). Similarly, there was an association between the odds of smoking tobacco and health-constraining features such a distant proximity of health-constraining features was related to lower odds of smoking tobacco (compared to D1, D8: AOR=0.631 [0.516, 0.772], D9: AOR=0.739 [0.595, 0.919], D10: AOR=0.892 [0.695, 1.146]). There was no association between smoking tobacco and health-promoting features.

3.3.2 Mental health

In general, the absence of ‘bads’ predicted lower odds of depression (compared to D1, D6: AOR=0.834 [0.732, 0.950], D7: 0.825 [0.723, 0.941], D8: AOR=0.773 [0.673, 0.888], D9: AOR=0.712 [0.609, 0.832], D10: AOR=0.690 [0.571, 0.834]). No statistically significant association for ‘goods’ decile and odds of depression. An absence of ‘bads’ was also related to lower odds of anxiety (compared to D1, D7: 0.813 [0.700, 0.944], D8: 0.754 [0.644, 0.883], D9: 0.681 [0.569, 0.814], but not for D10 (AOR=0.812 [0.656, 1.006]). Only the decile with most ‘goods’ was related to lower odds of anxiety (AOR=0.810 [0.657, 0.999]). Psychological distress was consistently related to health-constraining features (e.g., compared to D1, D9: AOR=-0.132 [-0.165, -0.098], but inconsistent associations were noted for health-promoting features and psychological distress.

3.3.3 Physical health

Some consistent associations were observed for both type II diabetes and BMI where closer proximity to health-promoting features was related to lower odds of type II diabetes and lower BMI, and closer proximity to health-constraining features was related to higher odds of type II diabetes and higher BMI.

INSERT TABLE 2, 3 AND 4 HERE

4. Discussion

Using a national probability sample of New Zealand adults, this cross-sectional and pre-registered study investigated the associations between the type of environment adults reside within and their self-reported health behaviours, as well as mental and physical health outcomes. Specifically, our analyses employed the newly developed Healthy Location Index (HLI) to identify health-promoting and health-constraining environmental features around the places people live. Our analyses then related these environmental data with health behaviours such as smoking tobacco and vaping, mental health outcomes including depression, anxiety, and psychological distress, and physical health outcomes of body mass index and type II diabetes.

Results demonstrated several notable associations between health-promoting and -constraining features, as represented by the HLI, and the health behaviours and health outcomes included in the NZAVS sample. While this supports several previous studies which have related health-promoting and health-constraining features to mental health (9, 37), we extend evidence by demonstrating small but statistically significant associations with physical health outcomes, mental health outcomes, and novel health behaviours such as vaping. When we modelled the health-constraining and health-promoting deciles, our data reveal that health-constraining environmental features were related to the mental health outcomes of anxiety, depression, and psychological distress. Similarly, health-constraining features were associated with vaping and smoking. However, both health-promoting *and* health-constraining environmental features were associated with physical health outcomes of BMI and type II diabetes. While there were consistencies seen within the deciles of exposure, the combined category of the HLI was more inconsistently related to health behaviours and outcomes. Significantly more NZAVS participants resided within areas classified as 'neither' areas in the combined HLI measures with much smaller numbers of participants in the solely health-promoting and health-constraining areas which may have contributed to some of the inconsistencies seen when using the overall combined HLI measure.

In our study, health-constraining environmental features were associated with all health behaviours and health outcomes especially when modelled as deciles of exposure. This supports a plethora of previous evidence that has confirmed the importance of creating healthy environments and limiting the proliferation of health-constraining features (38). For instance, objective measures of environments including factors such as neighbourhood quality, quantity of green space and land-use mix have been associated with psychological distress (28). More recent research which utilised high-resolution air pollution data found evidence for an association between exposure to higher levels of air pollution at age 12 and greater odds of developing depression at age 18 (49). Moreover, the Access to Healthy Assets and Hazards (AHAH) index of 14 health-related features of neighbourhoods in the UK demonstrated no association between the index with physical health measures, but a significant association to mental wellbeing (37). Importantly, this study also confirms a recent study which utilised pooled New Zealand Health Survey data from the Ministry of Health to show how unhealthy environments in the HLI were associated with depression, anxiety and psychological distress (9). Specifically, the previous study showed that compared to those individuals who resided within the unhealthiest environments, there was a steady reduction in the odds of adverse mental health outcomes and psychological distress as the environment became more health-promoting (9). However, we now extend this evidence to show associations exist with health behaviours and physical health outcomes as well using a distinct national New Zealand sample.

While there were consistent associations between health-constraining features and health behaviours or mental and physical health outcomes, the combined HLI was differentially associated with each health outcome and behaviour. Specifically, health promoting and health constraining features were associated only with physical health outcomes of BMI and type II diabetes (see Table 4). This suggests that the combination of health-promoting and -constraining features may be relevant for some conditions, but not others. This is similar to recent evidence which emphasises the importance of capturing multiple facets of the environment (31, 44, 50-54). Specifically, in a large sample of Dutch adults which showed that associations of combined exposures to surrounding green, air pollution and traffic noise on mental health were greater than single exposure models (51). Other UK research using UK biobank data showed that the benefits of PA facilities may be undermined by unhealthy local food environments. Specifically, the relationship between physical activity facilities and BMI was noticeably

attenuated among those individuals with more takeaway stores near home (44). The neighbourhoods we reside within are clearly multidimensional and further research should investigate how aspects may interact to influence behaviour and health outcomes.

Our study supports policy which has started to recognise the importance of addressing health constraining environments and creating healthy environments. Policymakers and organisations can use this evidence alongside other studies to advocate for the restriction of proliferation of health-constraining environmental features (31, 38). This will be important in the future considering the increasingly rapid global process of urbanisation. In research and policy, we often acknowledge the determinants of health are complex and include wider structural, environmental and political determinants. However, our public health strategies and interventions are overwhelmingly focused on individual-level interventions and associated factors (55-58). Nevertheless, the influence of wider upstream factors which includes environmental features on mental health behaviours and health outcomes are receiving renewed and increasing recognition in international research and policy. Within New Zealand this change in emphasis also aligns with ongoing New Zealand government health system reforms to shift the focus of the health system to prevention (59).

Our investigation is strengthened by the use of multiple environmental features, both health-constraining and health-promoting within the HLI, a unique dataset at a nationwide level. We also make use of a large national probabilistic sample of New Zealand adults from the New Zealand Attitudes and Values Survey. This sample also includes several health outcomes and behaviours comprising novel behaviours like vaping which are seldom investigated in prior research. While these are notable strengths, there are several limitations to consider when interpreting our results. First, our data are cross-sectional which limits our ability to draw causal inferences. Future research should explore longitudinal associations and attempt to provide evidence of temporal precedence of environmental features' influence on health outcomes. Second, our geospatial data does not contain any information on actual environmental use and thus we are relying on a proximity-equals-usage argument which previous studies have shown to be flawed to same extent (60-62); however, such actual usage data may only serve to strengthen the associations seen for proximity data and the home remains an important anchor point from which daily activities occur (63). Third, we rely on proximity rather than availability as our geospatial measure of access; however, data from the HLI are only available with proximity measures and previous research has shown proximity and availability measures to be highly correlated (64). Finally, it is plausible that associations vary spatially. Future research could investigate this further by exploring spatial autocorrelation or using spatial econometrics models such as spatial-lag regression to explore more local effects in large population-level datasets. An important area moving forward in this research domain will be exploring how the HLI is related to health outcomes specifically for disadvantaged populations and marginalised groups who tend to be more highly exposed to adverse environments and to share a higher burden of disease (65).

5. Conclusion

The current research examines the associations between health-constraining and health-promoting environmental features with physical and mental health outcomes as well as health behaviours. Using a unique Healthy Location Index (HLI) distinguishing between health-constraining and health-promoting environments, and self-report data from a national probability sample of adults, we find that the presence of health-constraining environments are associated with increased mental health outcomes including depression, anxiety and psychological distress, physical health outcomes including BMI and Type II diabetes, and negative health behaviours such as smoking and vaping. By contrast, health-promoting environmental features were only associated with physical health outcomes including BMI and type II diabetes, and not health behaviours or mental health outcomes. While the statistically significant associations were often small in effect, the findings replicate international and New Zealand results and provide important insight on the relationship between people's physical living environments on health behaviours and health outcomes. Moreover, it highlights the need for policy that reduces the presence of health-constraining environments to promote better societal health.

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Tables and figures

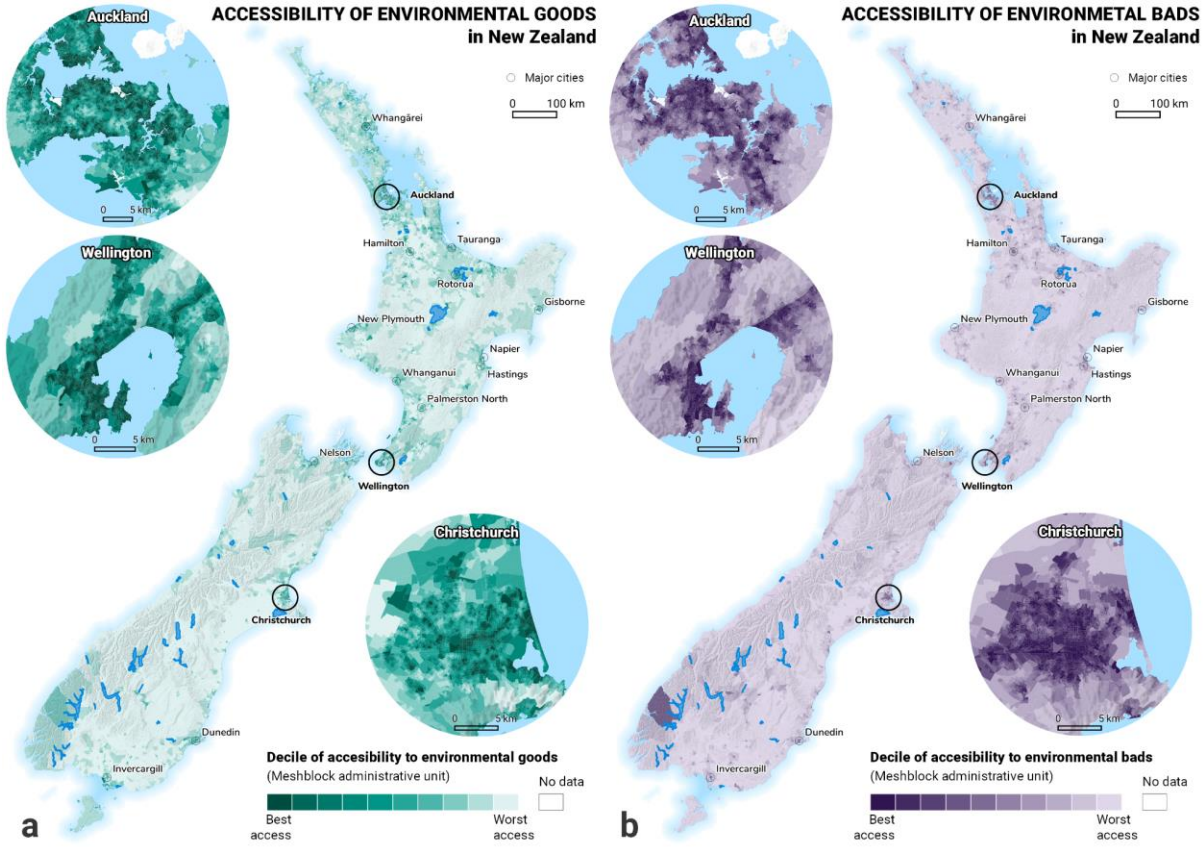

Figure 1. The spatial patterning of environmental 'goods' (a) and 'bads' (b) in New Zealand and urban areas of Auckland, Christchurch, and Wellington

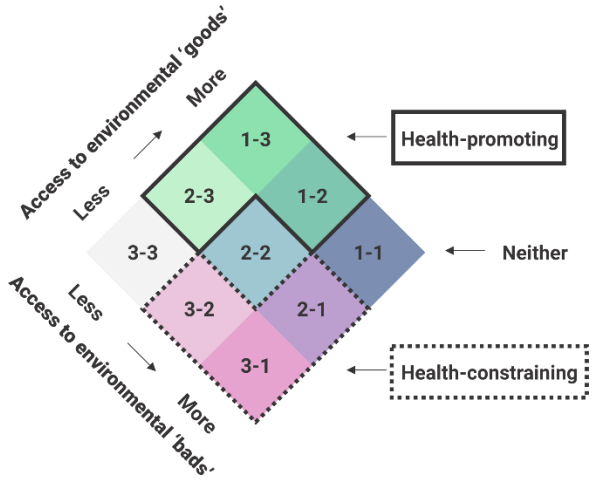

Figure 2. Final combinations for the Healthy Location Index (HLI) for access to health-promoting and health-constraining environments. Note: 1 denotes the best access, 3 denotes the worst access; e.g. 1-3 means the best access to 'goods' and the worst access to 'bads' – the most health promoting environment.

Table 1. Socio-demographic, health behaviours and health outcomes for study sample.

	Data
Sociodemographic data	
Age	
Mean (SD)	49.09 (13.86) years
Gender	
Male	37.2% (*n* = 17,810)
Female	62.8% (*n* = 30,020)
Ethnicity	
Maori	10.1% (*n* = 4,697)
Pacific	1.9% (*n* = 870)
Asian	5.2% (*n* = 2,411)
European/other	82.8% (*n* = 38,502)
Education	
No qualification	2.7% (*n* = 1,226)
Level 1 certificate	11.0% (*n* = 5,098)
Level 2 - certificate	5.6% (*n* = 2,571)
Level 3 - certificate	13.4% (*n* = 6,214)
Level 4 - certificate	6.1% (*n* = 2,802)
Level 5 - certificate/diploma	8.0% (*n* = 3,680)
Level 6 - graduate certificate	4.7% (*n* = 2,169)
Level 7 - bachelor degree	27.0% (*n* = 12,476)
Postgraduate certificate	10.9% (*n* = 5,028)
Masters degree	8.4% (*n* = 3,877)
Doctorate degree	2.4% (*n* = 1,122)
Health behaviours	
C**urrently vape or use e-cigarette**	
Yes	2.8% (*n* = 1,307)
No	97.2% (*n* = 45,419)
Ever vaped or used e-cigarette	
Yes	4.9% (*n* = 2,278)
No	95.1% (*n* = 44,448)
Currently smoke tobacco cigarettes	
Yes	7.4% (*n* = 3,454)
No	92.6% (*n* = 43,272)
Ever smoked tobacco cigarettes	
Yes	36.5% (*n* = 17,178)
No	63.5% (*n* = 29,867)
Exercise hours per week	
Mean (SD)	5.60 (7.69) hours
Health outcomes	
Depression	
Yes	14.5% (*n* = 6,813)
No	85.5% (*n* = 40,266)
Anxiety	
Yes	10.2% (*n* = 4,797)
No	89.8% (*n* = 42,242)
Psychological distress (0-4)	
Mean (SD)	0.89 (0.69)
Body mass index	
Mean (SD)	26.22 (8.08)
Type II diabetes	
Yes	3.6% (*n* = 1,674)
No	96.4% (*n* = 45,365)
Gambling disorder	
Yes	0.0% (*n* = 1)
No	100.0% (*n* = 46,885)
Alcohol addiction disorder	
Yes	0.1% (*n* = 33)
No	99.9% (*n* = 46, 853)

Note: data are displayed n (%) or as mean (standard deviation (SD)).

Table 2. The frequency or mean (standard deviation) of health outcomes and behaviours by HLI category.

	Depression		Anxiety		Type II diabetes		Psychological distress		BMI		Currently vape/e-cig		Ever vaped		Currently smoke tobacco		Ever smoked	
	N (yes)	%	N (yes)	%	N (yes)	%	Mean	SD	Mean	SD	N (yes)	%	N (yes)	%	N (yes)	%	N (yes)	%
HLI category																		
Health-promoting																		
1-3	79	12.9	57	9.3	16	2.6	0.82	0.61	25.80	7.36	20	3.3	31	5.1	39	6.4	226	36.9
2-3	446	12.5	296	8.3	99	2.8	0.80	0.64	26.03	7.69	83	2.3	154	4.3	215	6.0	1,333	37.2
1-2	903	14.2	639	10.1	225	3.5	0.89	0.69	26.05	7.83	185	2.9	317	5.0	424	6.7	2,243	35.3
Neither																		
3-3	965	11.8	662	8.1	216	2.6	0.81	0.65	26.16	7.78	199	2.5	331	4.1	592	7.3	3,086	37.8
2-2	1,610	14.5	1,118	10.3	441	4.1	0.89	0.69	26.40	8.37	281	2.6	514	4.8	785	7.3	3,869	35.6
1-1	1,321	16.7	939	12.1	290	3.7	0.95	0.71	26.08	8.10	252	3.3	437	5.7	618	8.0	2,916	37.5
Health-constraining																		
3-2	459	14.3	317	10.1	146	4.6	0.90	0.69	26.53	8.56	83	2.7	152	4.9	246	7.9	1,167	37.1
2-1	873	15.4	648	11.7	207	3.7	0.95	0.73	26.25	8.27	167	3.0	281	5.1	458	8.3	1,981	35.7
3-1	99	17.7	68	12.2	24	4.3	0.97	0.75	26.77	8.14	27	4.9	41	7.4	52	9.4	214	38.3

Table 3. Investigating associations between HLI, depression, anxiety, type II diabetes, BMI, vaping and tobacco smoking using mixed effects models with random intercept with individuals nested within meshblocks.

		Depression		Anxiety		Type II diabetes		BMI		Psychological distress		Current vaper		Current tobacco smoker	
		AOR [95% CI]	**P**	**AOR [95% CI]**	**P**	**AOR 95% CI**	**P**	**b [95% CI]**	**P**	**b [95% CI]**	**P**	**AOR [95% CI]**	**P**	**AOR [95% CI]**	**P**
Health-promoting	**1-3**	0.901 [0.697, 1.164]	0.427	0.942 [0.704, 1.261]	0.692	0.596 [0.346, 1.027]	0.063	-0.546 [-1.173, 0.080]	0.088	-0.031 [-0.085, 0.021]	0.245	1.578 [0.978, 2.546]	0.061	1.067 [0.742, 1.534]	0.726
	2-3	**0.855 [0.758, 0.965]**	**0.011**	**0.850 [0.739, 0.977]**	**0.023**	**0.634 [0.499, 0.806]**	**0.000**	**-0.452 [-0.745, -0.159]**	**0.002**	**-0.031 [-0.056, -0.006]**	**0.015**	0.932 [0.711, 1.220]	0.608	**0.822 [0.688, 0.982]**	**0.031**
	1-2	0.978 [0.889, 1.075]	0.648	1.012 [0.909, 1.127]	0.822	**0.833 [0.696, 0.998]**	**0.048**	**-0.303 [-0.543, -0.063]**	**0.013**	0.012 [-0.008, 0.032]	0.254	1.204 [0.982, 1.477]	0.074	0.961 [0.836, 1.106]	0.587
Neither	**3-3**	**0.766 [0.699, 0.840]**	**0.000**	**0.771 [0.693, 0.857]**	**0.000**	**0.651 [0.544, 0.779]**	**0.000**	**-0.328 [-0.552, -0.105]**	**0.004**	**-0.046 [-0.065, -0.026]**	**0.000**	0.939 [0.771, 1.145]	0.538	0.970 [0.855, 1.100]	0.637
	2-2	REF		REF		REF		REF		REF		REF		REF	
	1-1	**1.165 [1.069, 1.270]**	**0.000**	**1.163 [1.055, 1.282]**	**0.002**	0.941 [0.797, 1.112]	0.480	**-0.242 [-0.468, -0.016]**	**0.036**	**0.043 [0.023, 0.062]**	**0.000**	**1.289 [1.068, 1.556]**	**0.008**	**1.151 [1.015, 1.305]**	**0.029**
Health-constraining	**3-2**	0.945 [0.837, 1.066]	0.362	0.933 [0.812, 1.073]	0.334	1.078 [0.872, 1.332]	0.487	0.083 [-0.224, 0.391]	0.595	-0.004 [-0.030,0.022]	0.754	0.989 [0.758, 1.291]	0.940	0.941 [0.793, 1.119]	0.497
	2-1	1.039 [0.943, 1.145]	0.437	1.103 [0.989, 1.230]	0.077	0.969 [0.806, 1.164]	0.739	-0.089 [-0.339, 0.161]	0.485	**0.052 [0.031, 0.074]**	**0.000**	1.148 [0.928, 1.421]	0.202	**1.161 [1.011, 1.333]**	**0.034**
	3-1	1.186 [0.928, 1.515]	0.172	1.146 [0.867, 1.516]	0.337	1.203 [0.769, 1.881]	0.418	0.408 [-0.254, 1.071]	0.227	**0.062 [0.005, 0.119]**	**0.033**	**1.806 [1.149, 2.837]**	**0.010**	1.259 [0.894, 1.774]	0.186

Multi-level models adjusted for age, gender, ethnicity, education and exercise with individuals nested within 2018 meshblocks. Receiver operating characteristic (ROC) Area Under Curve (AUC): depression=0.62; anxiety=0.66; type II diabetes=0.77; BMI=0.67; psychological distress=0.68; current vaper=0.68; current smoker=0.70.

Table 4. Investigating associations between health-promoting and health-constraining environmental features and physical and mental health outcomes using mixed effects models with random intercept with individuals nested within meshblocks.

	Depression		**Anxiety**		**Type 2 Diabetes**		**BMI**		**Psychological distress**		**Current vaper**		**Current smoker**	
	AOR [95% CI]	P	AOR [95% CI]	P	AOR [95% CI]	P	b [95% CI]	P	b [95% CI]	P	AOR [95% CI]	P	AOR [9% CI]	P
Bads access decile														
1 (best access to bads)	REF		REF		REF		REF		REF		REF		REF	
2	0.974 [0.859, 1.103]	0.678	0.971 [0.845, 1.117]	0.688	0.828 [0.645, 1.063]	0.141	-0.044 [-0.374, 0.284]	0.790	**-0.037 [-0.065, -0.008]**	**0.010**	**0.777 [0.606, 0.996]**	**0.047**	0.905 [0.757, 1.081]	0.273
3	0.987 [0.871, 1.117]	0.838	0.975 [0.848, 1.121]	0.728	0.952 [0.748, 1.213]	0.695	0.118 [-0.211, 0.448]	0.482	**-0.043 [-0.071, -0.014]**	**0.003**	**0.600 [0.461, 0.781]**	**0.000**	0.869 [0.727, 1.040]	0.127
4	0.929 [0.819, 1.055]	0.259	0.917 [0.795, 1.057]	0.234	1.001 [0.787, 1.273]	0.991	0.050 [-0.283, 0.384	0.766	**-0.061 [-0.090, -0.032]**	**0.000**	**0.707 [0.546, 0.915]**	**0.009**	**0.796 [0.663, 0.956]**	**0.015**
5	0.913 [0.804, 1.038]	0.168	0.827 [0.714, 0.957]	0.011	0.933 [0.732, 1.190]	0.580	0.181 [-0.154, 0.516]	0.290	**-0.086 [-0.115, -0.057]**	**0.000**	**0.638 [0.490, 0.832]**	**0.001**	0.847 [0.706, 1.016]	0.074
6	**0.834 [0.732, 0.950]**	**0.006**	0.886 [0.766, 1.025]	0.104	**0.770 [0.600, 0.990]**	**0.042**	-0.097 [-0.433, 0.239]	0.571	**-0.062 [-0.092, -0.033]**	**0.000**	**0.595 [0.453, 0.781]**	**0.000**	**0.723 [0.600, 0.873]**	**0.001**
7	**0.825 [0.723, 0.941]**	**0.004**	**0.813 [0.700, 0.944]**	**0.007**	0.777 [0.603, 1.000]	0.051	-0.087 [-0.429, 0.253]	0.614	**-0.098 [-0.128, -0.069]**	**0.000**	0.769 [0.591, 1.001]	0.052	**0.687 [0.567, 0.833]**	**0.000**
8	**0.773 [0.673, 0.888]**	**0.000**	**0.754 [0.644, 0.883]**	**0.000**	**0.580 [0.441, 0.762]**	**0.000**	**-0.396 [-0.749, -0.043]**	**0.028**	**-0.112 [-0.143, -0.082]**	**0.000**	**0.605 [0.452, 0.807]**	**0.001**	**0.631 [0.516, 0.772]**	**0.000**
9	**0.712 [0.609, 0.832]**	**0.000**	**0.681 [0.569, 0.814]**	**0.000**	**0.523 [0.386, 0.708]**	**0.000**	**-0.554 [-0.943, -0.165]**	**0.005**	**-0.132 [-0.165, -0.098]**	**0.000**	**0.633 [0.459, 0.827]**	**0.005**	**0.739 [0.595, 0.919]**	**0.006**
10 (worst access to bads)	**0.690 [0.571, 0.834]**	**0.000**	0.812 [0.656, 1.006]	0.058	**0.388 [0.263, 0.572]**	**0.000**	**-0.591 [-1.055, -0.126]**	**0.013**	**-0.094 [-0.134, -0.053]**	**0.000**	0.723 [0.495, 1.054]	0.092	0.892 [0.695, 1.146]	0.373
Goods access decile														
1 (best access to goods	REF		REF		REF		REF		REF		REF		REF	
2	1.072 [0.950, 1.208]	0.256	1.051 [0.918, 1.203]	0.467	1.057 [0.828, 1.350]	0.651	0.189 [-0.121, 0.500]	0.233	0.022 [-0.004, 0.049]	0.100	1.097 [0.856, 1.406]	0.461	1.147 [0.959, 1.371]	0.131
3	1.088 [0.964, 1.227]	0.170	1.063 [0.928, 1.218]	0.376	1.151 [0.907, 1.460]	0.246	0.125 [-0.186, 0.437]	0.430	**0.032 [0.005, 0.059]**	**0.018**	0.948 [0.733, 1.227]	0.688	1.137 [0.950, 1.361]	0.161
4	1.014 [0.897, 1.147]	0.816	0.959 [0.833, 1.103]	0.559	1.208 [0.949, 1.537]	0.123	0.186 [-0.128, 0.501]	0.246	0.015 [-0.012, 0.042]	0.275	0.943 [0.726, 1.226]	0.665	1.100 [0.916, 1.320]	0.306
5	1.064 [0.939, 1.205]	0.328	1.031 [0.895, 1.188]	0.664	1.220 [0.956, 1.556]	0.109	**0.494 [0.174, 0.815]**	**0.002**	0.017 [-0.010, 0.045]	0.217	0.772 [0.583, 1.020]	0.069	1.193 [0.993, 1.434]	0.059
6	1.002 [0.884, 1.136]	0.971	1.035 [0.899, 1.192]	0.626	**1.338 [1.053, 1.701]**	**0.017**	**0.411 [0.092, 0.730]**	**0.012**	0.022 [-0.004, 0.050]	0.108	0.895 [0.684, 1.171]	0.419	1.112 [0.925, 1.337]	0.257
7	1.023 [0.899, 1.163]	0.726	1.031 [0.891, 1.192]	0.679	1.128 [0.875, 1.455]	0.351	**0.341 [0.015, 0.668]**	**0.040**	**0.034 [0.005, 0.062]**	**0.018**	0.941 [0.715, 1.237]	0.663	1.100 [0.910, 1.329]	0.324
8	1.034 [0.903, 1.184]	0.627	1.011 [0.867, 1.180]	0.882	**1.323 [1.018, 1.720]**	**0.036**	**0.443 [0.099, 0.786]**	**0.011**	0.028 [-0.001, 0.057]	0.063	0.871 [0.650, 1.166]	0.354	1.116 [0.915, 1.361]	0.275
9	0.963 [0.827, 1.122]	0.636	0.947 [0.796, 1.128]	0.548	**1.510 [1.126, 2.023]**	**0.006**	**0.478 [0.097, 0.859]**	**0.014**	0.009 [-0.023, 0.042]	0.572	0.904 [0.655, 1.248]	0.542	1.170 [0.941, 1.453]	0.156
10 (worst access goods)	0.966 [0.809, 1.155]	0.711	**0.810 [0.657, 0.999]**	**0.049**	**1.511 [1.067, 2.138]**	**0.020**	**0.916 [0.481, 1.352]**	**0.000**	-0.003 [-0.041, 0.034]	0.853	0.845 [0.581, 1.227]	0.376	1.051 [0.819, 1.346]	0.696

Multi-level models adjusted for age, gender, ethnicity, education and exercise with individuals nested within 2018 meshblocks. Receiver operating characteristic (ROC) Area Under Curve (AUC): Depression=0.67; Anxiety=0.63; Type II Diabetes=0.77; BMI=0.67; Psychological distress=0.68; Current vaper=0.67; Current smoker=0.65.