Health & Place 94 (2025) 103479

Contents lists available at ScienceDirect

Health and Place

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

Nature contact and health risk Behaviours: Results from an 18 country study

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ARTICLE INFO

Keywords:
Greenspace
Nature visits
Health risk behaviours
Smoking
Alcohol

ABSTRACT

Emerging evidence suggests that residential greenspace is associated with a lower prevalence of health risk behaviours, but it remains unclear whether these effects are generalizable across countries or different types of nature contact. Using representative cross-sectional samples from 18 countries/regions, we examined the associations between two types of nature contact (greenspace, nature visits), current smoking and everyday drinking. After controlling for a range of covariates, greenspace was inversely associated with current smoking and everyday drinking. Visiting natural spaces at least once a week was linked to a lower prevalence of current smoking, but unrelated to everyday drinking. Increasing residential greenspace could be a promising strategy for reducing multiple health risk behaviours, whilst visit-based interventions may be a more appropriate target for smoking cessation.

1. Introduction

Modifiable health risk behaviours, such as smoking and alcohol misuse are major determinants of morbidity and mortality worldwide (World Health Organisation, 2023). Smoking increases the risk of cardiovascular disease, cancer, and respiratory disease (World Health Organisation, 2023) even amongst occasional smokers (Hooshmand et al., 2024). Further, regularly exceeding recommended alcohol limits can adversely affect neurologic, cardiac, and gastrointestinal health (Esser et al., 2022). Such health risk behaviours tend to co-occur, with individuals who smoke also being more likely to exceed alcohol recommendations (Burton et al., 2023; Hughto et al., 2021). As combinations of risk behaviours are more detrimental to health than their cumulative individual effects (Alosaimi et al., 2023), identifying strategies that target multiple health risk behaviours are pivotal to fulfilling commitments outlined in the Global Noncommunicable Diseases (NCD) Compact 2020–2030 (World Health Organisation, 2022). An important emerging factor that could meet these requirements involves greater contact with natural environments.

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https://doi.org/10.1016/j.healthplace.2025.103479
Received 25 October 2024; Received in revised form 8 April 2025; Accepted 29 April 2025
Available online 13 May 2025

1.1. Greenspace and health behaviour

In the context of the current study, the term 'residential greenspace' is defined as the proportion of land comprised of vegetation and natural elements within an individual's immediate residential location, including private gardens (Taylor and Hochuli, 2017); further details on each nature contact variable are outlined in the '*Predictor Variables*' section of the Method. Alongside the well-established benefits to health and wellbeing (Banwell et al., 2024; White et al., 2021), emerging research suggests that the amount of residential greenspace is inversely related to health risk behaviours. A lower prevalence of health risk behaviours in greener neighborhoods has been observed in bivariate, single-country analyses of data in Australia (smoking;Astell-Burt et al., 2014a,b), Belgium (smoking; Van Herzele and de Vries, 2012) the United Kingdom (smoking; Astell-Burt et al., 2014), and Hong Kong (alcohol consumption; Wang et al., 2017). Moreover, a cross-sectional study in England found an inverse association between greenspace and smoking even after accounting for a range of socio-demographic factors known to covary with greenspace and health behaviours (e.g. income, Allen et al., 2017) and was not moderated by socio-economic status (Martin et al., 2020). This suggests that the associations were not simply due to certain socio-economic groups (i.e. individuals with higher incomes and higher educational attainment), who are less likely to smoke, residing in greener areas. Recent epidemiological studies have replicated these findings in different countries, observing lower rates of unhealthy consumption behaviours (e.g. smoking, marijuana use, binge drinking) amongst adults in Hong Kong (Zhang et al., 2023) and Canadian youths (Wiley et al., 2022) who live in greener neighborhoods. Whilst encouraging, research to date has comprised single-country studies focusing almost exclusively on residential greenspace. Therefore, it remains unclear whether nature-health risk behaviour relationships: a) extend beyond greenspace to other types of nature exposure (e.g. nature visits); and, b) are consistent across multiple countries using the same methodological approach.

1.2. Distinguishing between different types of nature contact

Prior research has predominantly focused on the amount of greenspace near individuals' homes, using the Normalized Difference Vegetation Index (NDVI) or land use datasets. Such analyses tacitly address only incidental contact with nature (Keniger et al., 2013). There is growing awareness of the importance of voluntarily engaging with nature (e.g. making intentional visits to natural spaces). For instance, individuals who regularly visit greenspaces (White et al., 2021; Arifwidodo and Chandrasiri, 2024), blue spaces (i.e. lakes, rivers, coasts; Elliott et al., 2023; Vitale et al., 2022; White et al., 2021) and natural spaces in general (Fian et al., 2024; Garrett et al., 2023; Samuelsson et al., 2021) report better psychological and physical health. Whilst some studies indicate that nature visits are a stronger determinant of health/wellbeing outcomes compared to the availability of residential greenspaces alone (Fian et al., 2024; Garrett et al., 2023; Kruize et al., 2020; White et al., 2021), others point to distinct types of nature contact having additive effects (Martin et al., 2024).

Despite the benefits of intentional nature visits being well-established for health/wellbeing outcomes, associations with health risk behaviours have received far less attention. Preliminary evidence linking nature visits to health risk behaviours comes from three lines of research. First, lower relapse rates have been observed amongst individuals undergoing drug and alcohol rehabilitation following nature-based treatment programmes involving time spent in nature (Díaz-Martínez et al., 2024). Second, Almog et al. (2022) observed that spending time in nature (broadly defined to include green and blue spaces) was associated with a less alcohol-related problems within a convenience sample of US adults. Third, experimental studies observing healthier behaviours (e.g. less smoking, healthier dietary choices) after participants view pictures of natural (*vs.* urban) scenes, indicate a causal link between more direct forms of nature exposure and health risk behaviours (Kao et al., 2019; W. Wu and Chiou, 2019).

Whilst making important contributions, the aforementioned studies focus on a single type of health risk behaviour and use small ($N < 350$) non-representative samples that are unable to adequately control for socio-demographic covariates known to predict health risk behaviours (e.g. population density and socio-economic status; (Bozzini et al., 2020; Reitsma et al., 2021). It is therefore unclear how generalizable these associations are: a) across different types of health risk behaviours; and b) at the population-level after controlling for socio-demographic covariates. Further, we are aware of no prior research examining the magnitude of the relationships between different types of nature contact (i.e. residential greenspace, nature visits) and health risk behaviours in comparison to socio-demographic factors. This type of comparison enables policy makers/practitioners to contextualise the magnitude of nature contact associations against long-established benchmarks and assess their relative importance.

1.3. Potential country variations

Recent reports from the World Health Organisation indicate that the prevalence of health risk behaviours varies considerably between countries (World Health Organisation, 2024a, 2024b). Further, whilst individuals from different cultures tend to express a preference for natural *versus* highly built environments (van den Berg, 2021), cultural factors affect people's aesthetic perceptions and preferences (Todorova et al., 2004; White et al., 2014), as well as their recreational use of natural spaces (Kusumaning Asri et al., 2021). Therefore, country-specific differences in health risk behaviours and environmental preferences have the potential to influence the strength of nature-behaviour associations. Indeed, recent studies using international datasets have indicated some county-level heterogeneity in the strength of nature – health associations (Martin et al., 2024; White et al., 2021), but this issue is yet to be examined within the context of health risk behaviours.

1.4. The current study

To address the gaps in prior research, we used representative cross-sectional samples from 18 countries/regions to examine.

1) The associations between *two* types of nature contact (residential greenspace [NDVI 250 m from home] and visits to natural spaces), and the prevalence of two health risk behaviours (current smoking and everyday drinking), after controlling for a wide range of socio-demographic covariates (e.g. population density, socio-economic status).
2) The consistency of nature-health risk behaviour associations between countries.
3) The magnitude of these associations compared to established socio-demographic predictors (income, education).

Congruent with prior research, we hypothesized that both types of nature contact (residential greenspace and nature visits) would be inversely associated with current smoking, exceeding and recommended alcohol guidelines. In line with the broader health benefits of nature (Martin et al., 2024) the contributions of different types of nature contact were expected to be cumulative.

2. Method

2.1. Participants & Procedure

Data were drawn from the BlueHealth International Survey (BIS; Grellier et al., 2017), a cross-sectional survey of 18,838 adults (9645 females) from 18 countries/regions (Bulgaria, California [USA], Canada,

Czech Republic, Estonia, Finland, France, Germany, Greece, Hong Kong [China], Ireland, Italy, the Netherlands, Portugal, Queensland [Australia], Spain, Sweden, and the United Kingdom). Representative samples, stratified by age, sex, and region, were obtained for each country/region by the international polling company YouGov using online survey panels, in four seasonal waves between June 2017 and April 2018. The dataset was selected for secondary analysis for its suitability to address our main research questions at the population-level. Specifically, the BIS includes data on: 1) smoking status and alcohol consumption; 2) comprehensive measures of incidental and intentional nature contact extending beyond blue spaces, to assess exposure to greenspaces and natural environments in general; 3) a wide range of socio-demographic variables known to co-vary with greenspace and health risk behaviours; and 4) representative multi-country samples. Full details pertaining to BIS methodology are available in the technical report (https://doi.org/10.17605/OSF.IO/7AZU2).

The current study used a sub-sample of the BIS dataset (N = 14,403) for cases where: 1) residential greenspace data were available and of sufficient quality; and 2) there were no missing data for any other variables. Comparison of the proportion of respondents within each socio-demographic group, indicated little variation (<0.05 %) as a function of the reduced sample, suggesting that there were no systematic biases in the exclusion of cases.

2.2. Measures

2.2.1. Outcome variables

Current Smoking. Using an item from the European Social Survey (European Research Infrastructure Consortium, 2020) respondents were asked: "Which of these best describes your smoking behaviour? This includes rolled tobacco but not pipes, cigars or electronic cigarettes". Response options were: 1. I have never smoked, 2. I have only smoked a few times, 3. I do not smoke now but I used to, 4. I smoke but not every day, 5. I smoke daily, and 6. Prefer not to answer. Respondents' smoking status was dichotomized into current smokers (N = 3424; 4 & 5) *vs.* non-smokers (including former smokers, N = 10,979, 1–3). Those who preferred not to answer (N = 177) were excluded from the analyses.

Everyday drinking. Consistent with the European Social Survey (European Research Infrastructure Consortium, 2020) respondents were asked: "In the last 12 months, how often have you had a drink containing alcohol? This could be wine, beer, spirits, or other drinks containing alcohol" (1. Never, 2. Less than once a month, 3. Once a month, 4.2–3 times a month, 5. Once a week, 6. Several times a week, 7. Every day, and 8. Prefer not to answer. With a lack of consensus in public health guidelines for alcohol consumption levels between countries (OIV Collective Expertise, 2019), drinking status was dichotomized according to whether or not respondents reported drinking everyday (yes, N = 1014; no, N = 13,344). Daily drinking increases the risks of developing liver cirrhosis and the all-cause mortality (Llamosas-Falcón et al., 2022), and as such is a widely used indicator of problematic drinking behaviour (Narro et al., 2024). Respondents who preferred not to state their alcohol consumption (N = 45) were excluded from the analysis. Sensitivity analyses comparing the inclusion *vs.* exclusion of respondents who selected 'Never' (N = 2142), yielded consistent results (Supplementary Material 1). Therefore, the unconditional prevalence of everyday drinking (i.e. proportions amongst the entire sample, including non-drinkers) are reported here to maximize sample size.

2.2.2. Predictor Variables

Following previous research (Martin et al., 2024; Weinstein et al., 2015) a range of nature contact metrics were operationalized.

Incidental Contact (Residential Greenspace). This variable was determined using averaged Normalized Difference Vegetation Index (NDVI) values, which captures vegetation density within a given area. Values were derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) terra satellite imagery between June 2017 and March 2018 (i.e. time points temporally consistent with survey data collection). With no established standard for selecting NDVI buffers (Qu et al., 2020) and prior demonstrating that visual access to greenery predicts lower cravings for nicotine and alcohol (Martin et al., 2019) consistent with Hu et al. (2022) we used NDVI data at a 250 m resolution. Therefore, the measure in the current study represents vegetation density within each respondent's immediate residential surroundings, including private gardens. Values ranging between −1.0 and 1.0 (with higher values indicating a higher density of green vegetation) were assigned to each respondent based on the pixel value where their home geocode was located. Sensitivity analyses conducted on different categorizations (high *vs.* low, tertiles, quartiles, continuous variable) and resolutions of NDVI (250 m *vs* 1000 m) yielded largely consistent findings (Supplementary Material 2). Following previous epidemiological studies operationalizing NDVI as a categorical variable (Pereira et al., 2012) while also ensuring there were sufficient observations within each country, our final models expressed NDVI in tertiles, ranging from the lowest level of residential greenness (M = 0.31, SD = 0.08), to the highest (M = 0.70, SD = 0.06). The BIS does not include a comparable measure of incidental blue space (e.g. coasts, lakes, rivers) within the same 250 m radial buffer as NDVI, hence why this variable was greenspace-specific.

Intentional Contact (Nature Visits). This item was based on a question from Natural England's Monitor of Engagement with the Natural Environment Survey (2018), "In the last 12 months, how often, on average, have you spent your leisure time at green and blue spaces?"(1. More than once per day, 2. Every day, 3. Several times a week, 4. Once a week, 5. Once or twice a month, 6. Once every 2–3 months, 7. Once or twice and, 8. Never. This item was selected for analysis due to its: 1) comparability with Almog et al.'s (2022) preliminary study on nature visits (which included green and blue visits) and alcohol consumption; and 2) temporal consistency with the BIS alcohol consumption measure (i.e. a twelve-month period. Consistent with prior research (Martin et al., 2020; Shanahan et al., 2016) the item was dichotomized according to whether respondents visited at least once a week (*vs.* less than weekly).

2.2.3. Control variables

Control variables included: gender (female, male); age (18–29, 30–39, 40–49, 50–59, 60+); long-term limiting illness/disability (yes, no); completed higher education (yes, no); working status (unemployed, employed, in education, retired, other); marital status (married/cohabiting, single/widowed/divorced, undisclosed); dog ownership (yes, no); psychological connectedness to the natural world (Inclusion of Nature in Self Scale, Schultz, 2001); and quintiles of household income. To retain respondents who did not state their income (N = 1914), we created a sixth category of 'income undisclosed'. In the absence of an internationally consistent definition of what constitutes an urban area, following prior work (Dijkstra et al., 2022), a simple population density threshold was used to control for urban/rural residence. Specifically, we categorized respondents living in a grid cell with ≥150 people per km^2 to be living in an urban area and those with a grid cell of <150 people per km^2 as living in a rural area.

2.2.4. Analytical approach

Analyses were conducted using STATA 16 (StataCorp, College Station, TX) and visualizations were created using R- 4.0.2 software. A series of multilevel mixed-effects Poisson regressions with robust standard errors were used to examine the associations between nature contact and health risk behaviours. Following best practice guidelines for modelling clustered data (Barr et al., 2013), country/region of residence was included as random intercept, with nature contact variables specified as random slopes. This approach accounts for national-level respondent clustering, as well as cross-country variation in nature-behaviour associations. Survey weights were applied to ensure

national representativeness with regards to the sampling strata within each country (sex, age, and region of residence). Unadjusted models are reported in Supplementary Material 3.

Additionally, to assess the magnitude of the effects of nature contact on the outcome variables, where appropriate, their prevalence ratios were compared to those of relevant control variables. Previous research has noted lower prevalence of health risk behaviours amongst individuals who are highly educated, from higher income households and higher socioeconomic groups (Allen et al., 2017; Laaksonen et al., 2005; Reitsma et al., 2021) Accordingly, the prevalence ratio associated with increased nature contact (residential greenspace and nature visits) was compared to: a) having a higher vs. no higher education, and b) having an income in the 5th quintile (highest) vs. the first quintile (lowest). Comparisons to these benchmarks connect our findings to other disciplines and helps researchers and policymakers assess their relative importance.

Finally, following prior research, we reported a series of robustness checks, including: 1) greenspace by SES interactions; 2) associations between nature contact, ever-smoking and smoking cessation; 3) co-occurrence between different health (risk) behaviours; and 4) estimations of nature-behaviour associations by country/region (Burton et al., 2023; Hughto et al., 2021; Martin et al., 2024; Martin et al., 2020; Sun et al., 2022). Further detail regarding these robustness checks can be found with the Supplementary Materials.

3. Results

3.1. Preliminarily analyses

Residential greenspace exhibited a positive, though small, association with nature visits ($r = 0.04, p < .001$). The unadjusted prevalence of health risk behaviours, as a function of respondent characteristics is reported in Table 1. Approximately a quarter of respondents (24 %) were current smokers. Less than one tenth (7 %) reported drinking every day. In line with predictions, the proportion of current smokers decreased incrementally with each residential greenspace tertile (T1 = 27 %, T2 = 23 %, T3 [most greenspace] = 21 %), with the highest proportion of current smokers residing in the least green residential areas. Similarly, the proportion of individuals drinking daily was highest in the lowest tertile of residential greenspace (*T1* = 9 %, T2 = 6 %, T3 [most greenspace] = 6 %). At the bivariate level, there was no difference in proportion of current smokers amongst those who visited nature at least once a week, compared those who made less than weekly visits (24 % *vs*. 24 %). Contrary to predictions, a higher proportion of daily drinkers (*vs*. less frequent drinkers), visited natural spaces at least once a week (8 % *vs*. 6 %).

3.2. Main models

Fully adjusted mixed-effects Poisson regression models with robust standard errors estimating the adjusted prevalence ratios of health risk behaviours are reported in Table 2. All variance inflation factors (VIF) for model parameters were <3.34, indicating that multicollinearity was not an issue.

3.2.1. Incidental contact (residential greenspace)

The prevalence of current smoking was significantly lower in the highest (*vs*. lowest) tertile of residential greenspace ($PR = 0.87$, *95 % CIs* = 0.77, 0.98, $p = .024$). Similarly, there was a significantly lower prevalence of everyday drinking amongst respondents who resided in 2nd ($PR = 0.69$, *95 % CIs* = 0.59, 0.80, $p < .001$) and 3rd ($PR = 0.74$, *95 % CIs* 0.62, 0.89, $p = .001$) greenspace tertiles (*vs*. 1st tertiles).

3.2.2. Intentional contact (nature visits)

The prevalence rate of current smoking was significantly lower amongst respondents who visited natural spaces at least once a week (*vs*. < once a week; $PR = 0.91$; *95 % CIs* = 0.84, 0.99, $p = .030$). Contrary to predictions, there was a statistically non-significant positive association between exceeding recommended alcohol limits and visiting natural spaces at least once a week (*vs*. < once a week; $PR = 1.09$, *95 % CIs* = 0.09, 1.31, $p = .378$).

3.2.3. Control variables

Females (*vs*. males) had a lower prevalence of both current smoking ($PR = 0.89$, *95 % CIs* = 0.80, 0.98, $p = .017$) and everyday drinking ($PR = 0.48$, *95 % CIs* = 0.42, 0.54, $p < .001$). Older adults were more likely to be current smokers, or to exceed alcohol guidelines than those aged 18–29 years (e.g. 50–59 years: $PR = 1.25$, *95 % CIs* = 1.09, 1.44, p = .001 and $PR = 2.09$, *95 % CIs* = 1.59, 2.75, $p < .001$, respectively). Having a higher education (*vs*. no higher education) was associated with a lower prevalence of current smoking ($PR = 0.77$, *95 % CIs* = 0.70, 0.84, $p < .001$), but unrelated to everyday drinking ($PR = 0.94$, *95 % CIs* = 0.82, 1.06, $p = .296$). As household income increased, the prevalence of current smoking decreased incrementally; for everyday drinking, however, prevalence was highest amongst those in the highest income quintile (*vs*. lowest: $PR = 1.33$, *95 % CIs* = 1.05, 1.68, $p = .019$). Having a disability (*vs*. no disability) and owning a dog (*vs*. not owning a dog) were associated with higher rates of current smoking ($PR = 1.15$, *95 % CIs* = 1.05, 1.25, $p = .002$; $PR = 1.38$, *95 % CIs* = 1.27, 1.51, $p < .001$, respectively) and everyday drinking ($PR = 1.16$ *95 % CIs* = 1.03, 1.32, $p = .019$; $PR = 1.23$ *95 % CIs* = 1.09, 1.40, $p < .001$, respectively). The random effect terms indicated a small degree of country/region variance in the associations between: residential greenspace and health risk behaviours (current smoker: 95 % CIs = 0.00, 0.20; everyday drinking: 95 % CIs = 0.00, 0.02). For nature visits, variance in health (risk) behaviours as a function of country/region was higher for everyday drinking (95 % CIs = 0.02, 0.08), than current smoking (95 % CIs = 0.01, 0.03).

3.3. Robustness checks (Supplementary Materials 4–7)

There was little evidence of moderation by two measures of socio-economic status, in the greenspace tertiles where the differences in outcomes as a function of residential greenspace were most pronounced (see Supplementary Table S4a and S4b for full details), indicating that our findings were not simply due to socio-economic groups who are less likely to engage in these behaviours residing in greener areas. The findings were robust after adjustment for co-occurring health (risk) behaviours (smoking, drinking and physical activity, Supplementary Table S5) suggesting that the findings were not simply an artefact of shared variance between health risk behaviours. Attempts to uncover whether the associations between nature contact and current smoking, were attributable to a lower prevalence of ever smoking and/or a higher prevalence of smoking cessation, did not replicate prior research observing a higher prevalence of smoking cessation in high greenspace neighbourhoods (Supplementary Materials 6), (Martin et al., 2020). Finally, the pattern of nature-behaviour associations observed within our main models, were largely consistent between countries/regions for: a) residential greenspace and both domains of health risk behaviour, and b) nature visits and current smoking (Supplementary Materials 7). However, non-significant positive association between nature visits and the prevalence of everyday drinking observed within our main models, showed a greater degree of variation at the country/regional level. Notably, whilst the prevalence of everyday drinking increased with visit frequency for 7/18 countries/regions (Czech Republic, Canada, Queensland [Australia], Netherlands, France, Germany and California [USA]), for the remaining 11 countries/regions, there was little difference in the prevalence of everyday drinking as a function of nature visits.

3.4. Comparison to socio-demographics

Where statistically significant associations between greenspace and

Table 1
Respondent characteristics according to health risk behaviour status.

			Current smoker (N = 14,403)		Everyday drinking[a] (N = 14,358)	
	Total % (Raw Data)	**Total % (Weighted)**	**No[b]** (76.23 %)	**Yes[b]** (23.77 %)	**No[b]** (92.94 %)	**Yes[b]** (7.06 %)
Residential Greenspace (NDVI)						
1st Tertile (M = 0.31, least green)	33.77 %	34.08 %	73.38 %	26.62 %	91.14 %	8.86 %
2nd Tertile (M = 0.52)	32.91 %	33.03 %	76.67 %	23.33 %	93.77 %	6.23 %
3rd Tertile (M = 0.70, most green)	33.32 %	32.89 %	78.71 %	21.29 %	93.95 %	6.05 %
Nature visits						
< once a week	43.84 %	42.335 %	75.96 %	24.04 %	93.67 %	6.33 %
≥ once a week	56.16 %	57.67 %	76.42 %	23.58 %	92.41 %	7.59 %
Gender						
Male	48.80 %	48.16 %	75.17 %	24.83 %	90.21 %	9.79 %
Female	51.20 %	51.84 %	77.24 %	22.76 %	95.54 %	4.46 %
Age						
18–29	18.63 %	18.23 %	79.72 %	20.28 %	97.37 %	2.63 %
30–39	18.11 %	17.33 %	72.89 %	27.11 %	95.03 %	4.97 %
40–49	18.91 %	17.97 %	72.27 %	27.73 %	94.08 %	5.92 %
50–59	18.04 %	16.98 %	72.32 %	27.68 %	92.30 %	7.70 %
60+	26.31 %	29.49 %	81.56 %	18.44 %	88.09 %	11.91 %
Marital status						
Single/widowed/divorced	36.45 %	36.25 %	74.36 %	25.64 %	94.58 %	5.42 %
Married/cohabiting	58.98 %	59.33 %	77.08 %	22.92 %	91.77 %	8.23 %
Undisclosed	4.58 %	4.04 %	79.81 %	20.19 %	95.66 %	4.34 %
Higher education						
No	49.07 %	50.00 %	72.76 %	27.24 %	93.02 %	6.98 %
Yes	50.93 %	49.99 %	79.62 %	20.38 %	92.86 %	7.14 %
Working status						
Unemployed	6.51 %	6.18 %	73.28 %	26.72 %	93.99 %	6.01 %
Employed	55.42 %	53.89 %	73.91 %	26.09 %	93.85 %	6.15 %
In education	6.41 %	6.69 %	85.02 %	14.98 %	98.02 %	1.98 %
Retired	19.01 %	20.56 %	83.58 %	16.42 %	87.34 %	12.66 %
Other	12.65 %	12.76 %	71.94 %	28.06 %	94.29 %	5.71 %
Household income						
1st quintile (lowest)	15.76 %	16.08 %	70.84 %	29.16 %	94.97 %	5.03 %
2nd quintile	14.71 %	14.99 %	73.51 %	26.49 %	93.89 %	6.11 %
3rd quintile	15.59 %	16.21 %	75.49 %	24.51 %	91.85 %	8.15 %
4th quintile	17.01 %	17.64 %	77.45 %	22.55 %	92.17 %	7.83 %
5th quintile (highest)	22.84 %	21.87 %	78.07 %	21.93 %	91.00 %	9.00 %
Undisclosed	14.09 %	13.20 %	81.97 %	18.03 %	94.94 %	5.06 %
Dog owner						
No	69.97 %	68.94 %	78.85 %	21.15 %	93.39 %	6.61 %
Yes	30.03 %	31.06 %	70.47 %	29.53 %	91.95 %	8.05 %
Disability						
No	63.10 %	62.91 %	77.29 %	22.71 %	93.26 %	6.74 %
Yes	35.90 %	37.09 %	74.43 %	25.57 %	92.39 %	7.61 %
Nature Connectedness (INS)[c]	4.18 (1.64)	4.18 (1.64)	4.15 (1.63)	4.28 (1.68)	4.16 (1.63)	4.45 (1.74)
Urbanicity						
Rural	33.44 %	33.95 %	75.54 %	24.46 %	92.54 %	7.46 %
Urban	66.56 %	66.05 %	76.58 %	23.42 %	93.14 %	6.82 %
Country/region						
Queensland, AU	5.31 %	5.10 %	76.27 %	23.73 %	86.90 %	13.10 %
Bulgaria	5.60 %	6.32 %	62.08 %	37.92 %	87.21 %	12.79 %
California, US	5.72 %	5.19 %	86.60 %	13.40 %	93.97 %	6.03 %
Canada	5.47 %	5.52 %	76.01 %	23.99 %	92.19 %	7.81 %
Czech Republic	5.73 %	6.21 %	70.90 %	29.10 %	94.02 %	5.98 %
Estonia	5.10 %	5.32 %	73.07 %	26.93 %	97.37 %	2.63 %
Finland	5.63 %	6.13 %	81.26 %	18.74 %	97.26 %	2.64 %
France	5.69 %	6.13 %	75.45 %	24.55 %	91.16 %	8.84 %
Germany	5.44 %	6.05 %	73.13 %	26.87 %	94.81 %	5.19 %
Greece	5.15 %	4.27 %	64.88 %	35.12 %	96.49 %	2.15 %
Hong Kong, CN	5.22 %	2.45 %	89.01 %	10.99 %	99.14 %	0.86 %
Ireland	5.62 %	6.11 %	77.85 %	22.15 %	95.77 %	4.23 %
Italy	5.66 %	5.97 %	70.27 %	29.73 %	91.16 %	8.84 %
Netherlands	5.64 %	6.45 %	79.78 %	20.22 %	90.24 %	9.76 %
Portugal	5.02 %	5.21 %	77.33 %	22.67 %	87.85 %	12.15 %
Spain	5.60 %	5.41 %	70.11 %	29.89 %	89.90 %	10.10 %
Sweden	5.67 %	6.02 %	86.33 %	13.67 %	97.66 %	2.34 %
United Kingdom	6.73 %	6.11 %	86.43 %	13.57 %	92.93 %	7.07 %

Note: First two column percentages relate to total sample. All other percentages relate to % within each exposure category across each domain of health risk behaviour.
[a] Drinks alcohol every day [b]Using weighted data [c]Mean (Standard Deviation) reported for continuous variables.

Table 2
Fully-adjusted multilevel mixed-effects Poisson regression models, estimating the prevalence ratios (PR) and 95 % CIs for the associations between nature contact and health risk behaviours, controlling for covariates.

	Current Smoking (N = 14, 403)			Everyday drinking (N = 14, 358)		
	PR	**95 % CIs**	***p***	**PR**	**95 % CIs**	***p***
Residential Greenspace (NDVI)						
1st Tertile (M = 0.31, least green, ref)	–	–	–	–	–	–
2nd Tertile (M = 0.52)	0.94	(0.85, 1.04)	0.253	0.69	(0.59, 0.80)	<0.001
3rd Tertile (M = 0.70, most green)	0.87	(0.77, 0.98)	0.024	0.74	(0.62, 0.89)	0.001
Nature Visits						
<once a week (ref)	–	–	–	–	–	–
≥ once a week	0.91	(0.84, 0.99)	0.030	1.09	(0.09, 1.31)	0.378
Gender (female)	0.89	(0.80, 0.98)	0.017	0.48	(0.42, 0.54)	<0.001
Age						
18-29 (ref)	–	–	–	–	–	–
30–39	1.24	(1.11, 1.38)	<0.001	1.38	(1.04, 1.85)	0.028
40–49	1.23	(1.08, 1.40)	0.002	1.61	(1.21, 2.13)	0.001
50–59	1.25	(1.09, 1.44)	0.001	2.09	(1.59, 2.75)	<0.001
60+	1.06	(0.89, 1.26)	0.507	2.89	(2.19, 3.82)	<0.001
Marital status						
Single/widowed/divorced (ref)	–	–	–	–	–	–
Married/cohabiting	0.84	(0.77, 0.92)	<0.001	1.08	(0.94, 1.25)	0.274
Undisclosed	0.90	(0.74, 1.08)	0.246	1.16	(0.78, 1.70)	0.464
Higher education (yes)	0.77	(0.70, 0.84)	<0.001	0.94	(0.82, 1.06)	0.296
Working status						
Unemployed (ref)	–	–	–	–	–	
Employed	1.11	(0.97, 1.27)	0.121	0.87	(0.66, 1.15)	0.330
In education	0.63	(0.51, 0.78)	<0.001	0.50	(0.30, 0.84)	0.008
Retired	0.75	(0.61, 0.91)	0.004	1.21	(0.89, 1.63)	0.222
Other	1.10	(0.96, 1.26)	0.158	0.76	(0.55, 1.06)	0.105
Household income						
1st quintile (lowest, ref)	–	–	–	–	–	–
2nd quintile	0.93	(0.80, 1.08)	0.330	0.90	(0.70, 1.14)	0.378
3rd quintile	0.88	(0.77, 1.01)	0.077	1.22	(0.96, 1.54)	0.099
4th quintile	0.82	(0.72, 0.94)	0.003	1.19	(0.94, 1.50)	0.155
5th quintile (highest)	0.80	(0.69, 0.92)	0.002	1.33	(1.05, 1.68)	0.019
Undisclosed	0.72	(0.61, 0.85)	<0.001	1.03	(0.79, 1.33)	0.853
Dog owner (yes)	1.38	(1.27, 1.51)	<0.001	1.23	(1.09, 1.40)	0.001
Disability (yes)	1.15	(1.05, 1.25)	0.002	1.16	(1.03, 1.32)	0.019
Nature Connectedness (INS)	1.02	(1.00, 1.04)	0.061	1.03	(0.99, 1.07)	0.102
Urban	0.96	(0.89, 1.04)	0.291	0.89	(0.77, 1.02)	0.099
Intercept	0.27	(0.21, 0.35)	<0.001	0.04	(0.02, 0.06)	<0.001
Random effects (country/region)	**Variance**	**95 % CIs**		**Variance**	**95 % Cis**	
Residential Greenspace (NDVI)	0.00	(0.00, 0.20)		0.00	(0.00, 0.02)	
Nature Visits	0.02	(0.01.0.03)		0.03	(0.02, 0.08)	
Intercept	0.08	(0.04, 0.18)		0.01	(0.00, 0.02)	
				0.02	(0.01, 0.04)	
χ^2 (df)	442.81 (24) ***			401.16(24)***		
Log likelihood	−8779.41			−3348.45		
Marginal R^2	0.04			0.04		
Conditional R^2	0.16			0.17		

Notes: All models use survey weights. PR = Prevalence Ratio. $\chi 2$ (df) = Wald's Chi-Square Statistic (degrees of freedom). ***p < .001 Marginal R^2 includes only fixed effects and Conditional R^2 includes the random country effect.

behavioural outcomes were observed (i.e. current smoking and everyday drinking), the prevalence ratio associated with increased nature contact (greenspace and nature visits) was compared to: a) having completed a higher education vs. not; and b) having an income in the 5th quintile (highest) vs. the first quintile (lowest). For current smoking, living in the highest (3rd) tertile of residential greenspace was associated with a 13 % lower prevalence of current smoking, compared to living in the lowest greenspace tertile (PR = 0.87, 95 % CIs = 0.77, 0.98, p = .024). This was over half the size of the 23 % and 20 % lower prevalence associated with having a higher education (vs. not having a higher education; PR = 0.77, 95 % CIs = 0.70, 0.84, p < .001) and having an income in the 5th quintile (vs. 1st quintile, PR = 0.80, 95 % CIs = 0.69, 0.92, p = .002), respectively. Visiting natural spaces at least once a week was associated with 9 % lower prevalence of current smoking (vs. < once a week: PR = 0.91, 95 % CIs = 0.93, 1.03, p = .033), which was smaller than the reductions associated with both residential greenspace and the two socio-demographic comparators. Conversely, residing in the 2nd and 3rd greenspace tertiles (vs. 1st tertile) was associated with a 31 % and 26 % lower prevalence of everyday drinking (PR = 0.69, 95 % CIs 0.59, 0.80; p < .001, PR = 0.74, 95 % CIs = 0.62, 0.89 p = 001, respectively). This was far greater in magnitude than those associated with having a higher education (PR = 0.94, 95 % CIs = 0.82, 1.06, p = .296), but similar in magnitude, albeit in the opposite direction, to the 31 % higher prevalence in everyday drinking associated with having an income in the 5th quintile (PR = 1.31, 95 % CIs = 1.02, 1.69, p = .033). Overall, these comparisons suggest that, in relative terms, for being a current smoker, the effects of residential greenspace are greater in magnitude than those of nature visits, but around half the size of those associated with benchmark socio-demographics. For everyday drinking, the effects of residential greenspace exceeded those of education and were similar in magnitude to the higher prevalence associated with income.

4. Discussion

This study investigated the associations between two types of nature contact and the prevalence of two health risk behaviours using an international cross-sectional sample from 18 countries/regions. Our aims

were three-fold, to examine whether links between nature contact and health risk behaviours: 1) extend to different types of nature exposure, beyond residential greenspace, at the population-level after accounting for socio-demographic covariates; 2) are demonstrable across multiple countries using the same methodological approach; and 3) to assess the magnitude of nature-behaviour associations compared to well-established socio-demographic predictors.

4.1. Nature contact and health risk behaviours

Incidental nature contact (residential greenspace) was inversely related to both domains of health risk behaviours. Consistent with prior research (Martin et al., 2020; Wiley et al., 2022; Zhang et al., 2023), there was a lower prevalence of current smoking amongst individuals living in the highest greenspace tertile, compared to those who lived in the lowest tertile. Furthermore, there was a lower prevalence of everyday drinking for individuals living in the two highest (*vs*. lowest) greenspace tertiles. Extending prior work on nature and health risk behaviours in single-countries (Almog et al., 2022; Pereira et al., 2012; Wiley et al., 2022; Zhang et al., 2023), these associations were upheld after adjusting for a broader range of covariates, including country/region effects. This suggests that the relationships between greenspace and health risk behaviours generalize across a wide range of countries across two domains of health risk behaviour. Further, these associations were robust to different operationalisations of greenspace, and largely unmoderated by two measures of socio-economic status. Taken together, our findings suggest that high residential greenspace is independently associated with a lower prevalence of two distinct types of health risk behaviour, irrespective of the socio-demographic characteristics of the individuals who reside in these areas.

For intentional contact (nature visits) the findings were more mixed. Consistent with predictions, there was a lower prevalence of current smoking amongst individuals who visited natural spaces at least once a week (*vs.* less than weekly). This finding adds to evidence suggesting visiting natural environments is associated with positive health and wellbeing outcomes (Fian et al., 2024; Garrett et al., 2023; Samuelsson et al., 2021). That both greenspace and nature visits remained significant within the same models suggests that the benefits of these two types nature contact may be cumulative for reducing the prevalence of current smoking. This is consistent with additive effects of different types of nature contact observed for broader health and wellbeing outcomes (Martin et al., 2024).

Contrary to the Almog et al.'s (2022) findings that spending time in nature serves as a protective factor against problematic drinking, the frequency of nature visits exhibited an unexpected positive, but statistically non-significant, association to everyday drinking. The disparity in our findings may reflect methodological differences between studies, for example, the inclusion of different alcohol and nature measures (time in nature *vs.* visit frequency; Alcohol Use Disorders Identification Test *vs.* single item measure of consumption frequency). The lack of significant associations here could also be due the inclusion of a wider range of socio-demographics covariates (i.e. population density) within the current study that are known to influence alcohol outlet density and drinking behaviour (Sersli et al., 2025). Equally, our findings regarding county-level heterogeneity in the strength of this association (i.e. non-significant increase N = 7] *vs.* little association [N = 11] as a function of weekly nature visits) highlight potential cultural differences in the links between nature visits and everyday drinking. Future research might usefully explore whether cultural factors influence the association between nature visits and alcohol consumption.

As the inclusion of physical activity within our models (Supplementary Material 5) did not alter the relationships between nature contact and health risk behaviours, these effects are unlikely to be merely due to increased physical activity associated with living near or visiting natural spaces. Whilst speculative, there are several interconnected mechanisms through which increased nature contact may influence health risk behaviours. Whilst beyond the scope of the current study, there are several interconnected mechanisms through which nature contact may affect the prevalence of health risk behaviours. Natural environments have been associated with improved affect (Almog et al., 2022; Yao et al., 2021) and community cohesion (Clarke et al., 2023; Weinstein et al., 2015), as well reduced temporal discounting (Berry et al., 2019; Wu et al., 2025), and craving (Benvegnù et al., 2024; Martin et al., 2019). As each construct independently predicts lower engagement in health risk behaviours (Chan et al., 2024; Michalski et al., 2024; Saha et al., 2022; Syan et al., 2021), increased contact with the natural world could potentially influence health risk behaviour through an inter-play of cognitive, affective and social pathways.

The pattern of associations between socio-demographic covariates and our outcome variables reflect well-established social gradients in the prevalence of health risk behaviours. Our findings are in line with prior studies indicating a higher prevalence of health risk behaviours in males (*vs*. females), individuals with disabilities (*vs.* no disability), those with lower educational attainment (*vs.* higher education), and dog-owners (*vs.* not owning a dog), (Allen et al., 2017; Disney et al., 2023; Laaksonen et al., 2005; Surma et al., 2022). The prevalence of smoking and everyday drinking, as a function of age and income also replicate prior work ((Bjørnerud Korslund et al., 2023; Williams et al., 2016). Such consistency provides greater assurance in the robustness of our nature-behaviour associations.

Our comparisons to benchmark socio-demographics suggest that associations between nature contact and health risk behaviours may be quantitatively meaningful for potential public health intervention. For being a current smoker, the effects of residential greenspace were around half the size of those associated with benchmark socio-demographics known to predict smoking that are less amenable to change (e.g. education and income; Bjørnerud Korslund et al., 2023; Williams et al., 2016). For everyday drinking, the effects of residential greenspace exceeded those of education and were similar in magnitude to the higher prevalence associated with income. Overall, these estimates identify levels of residential greenspace as an overlooked environmental risk factor for engagement in health risk behaviours and highlight its potential protective value within this domain.

In relative terms, visiting natural spaces at least once a week exhibited weaker associations to health risk behaviours than residential greenspace and comparator socio-demographics. This is perhaps surprising, given some studies reporting that nature visits are a stronger predictor of broader health and wellbeing outcomes than incidental measures (Fian et al., 2024; Garrett et al., 2023; Kruize et al., 2020; White et al., 2021). Whilst speculative, it is possible that greenspace around the home constitutes a micro-restorative setting, with immediate visual access providing more regular restorative opportunities (Hartig et al., 2014) than those afforded by nature visits. Indeed, the cognitive and affective benefits of greenspace close to the home have been demonstrated elsewhere (Martin et al., 2024; Soga et al., 2021). Moreover, visual assess to greenery, but not the frequency of nature visits, predicts lower cravings for a range of substances, including nicotine and alcohol (Martin et al., 2019). Given that smoking and alcohol misuse often constitute habitual responses to everyday stressors (Jahnel et al., 2019) and cravings (Wemm et al., 2022) greenspace characteristics that are visually accessible may conceivably be most beneficial for attenuating these kinds of behaviours. With recent theory highlighting the potential for nature to promote resilience and attenuate the adverse health/wellbeing impact during times of stress (Nature-based biopsychosocial resilience theory, White et al., 2023) future research on nature and health risk behaviours might usefully incorporate measures of resilience to stressors.

4.2. Limitations

Whilst providing insights into the relationships between nature contact and health risk behaviours, we also recognize several limitations

in this study. First, the cross-sectional data limit our ability to make causal inferences. Despite experimental evidence demonstrating improvements in health risk behaviours following exposure to natural environments (Kao et al., 2019; Wu and Chiou, 2019), reverse causality cannot be ruled out (i.e. individuals already exhibiting healthier lifestyles selectively migrate towards more natural settings). Second, although we controlled for individual-level measures of socio-economic status, with no internationally consistent metric of area-level deprivation, there remains the possibility of residual confounding. Third, these results are based on self-reported data. Whilst self-reported health risk behaviours correlate strongly with objective indices (Vartiainen et al., 2002), due to well-known negative health consequences of smoking and excessive alcohol intake, we cannot rule out possible misclassifications in health risk behaviours due to social desirability bias. Fourth, data on the units of alcohol consumed were not collected in the survey. Although consuming alcohol everyday increases the risks of developing liver cirrhosis and the all-cause mortality (Llamosas-Falcón et al., 2022), and as such is a widely-used indicator of problematic drinking behaviour (Narro et al., 2024), it does not represent a precise measure of consumption. Moreover, varied guidelines for alcohol consumption levels between countries (OIV Collective Expertise, 2019) mean that public health advice against drinking every day may not be available in each country included in the current study. Fifth, despite following a similar approach to prior work comparing greenspace indices across countries/regions (White et al., 2021), we recognize that NDVI values vary within and between different geographies and climate zones, potentially introducing error into our models. Future research might usefully explore this issue further, for instance by accounting for factors such as biogeographic realm. Finally, as with much previous observational research, the current study focused exclusively on residence-based measures of greenspace. Consequently, other potentially important green space exposures, for instance greenspace around workplace, schools or commuting routes (Wang et al., 2021) were unaccounted for here. Sixth, we recognize that our findings are based on data from predominantly westernised, affluent countries. Given that a large proportion of natural spaces in developing countries are depended upon for agriculture, rather than recreation (Kusumaning Asri et al., 2021), the generalisability of our findings to developing countries is unclear. Studies utilizing longitudinal designs, as well as more comprehensive measures of nature exposure and health risk behaviours, across a broader range of countries, are needed to assess the robustness of our findings.

4.3. Implications

Whilst recognizing the correlational nature of the dataset, should further research corroborate that the associations observed here are causal, then our findings have a number of potential practical implications. Improvements to the provision and maintenance of residential greenspace, for instance through greener infrastructure or urban greening strategies, represents a promising place-based strategy for reducing multiple health risk behaviour at the population-level. With competing demands for land use and widespread budgetary constraints (Public Health England, 2020), local authorities might consider the prioritization of residential greenspace within communities with a higher prevalence of health risk behaviour, as part of the wider plan to reduce local health inequalities. Further, sensitivity analyses comparing NDVI at 250 m and 1000 m resolutions (Supplementary Material 2) indicated that greenery nearby the home was a stronger predictor of both domains of health risk behaviour, relative to greenspace within the wider neighborhood. If these findings are substantiated by further work, then 'streetscape' greenery currently being implemented with urban cities to mitigate flood risks and urban heat island effects (e.g. Mayor of London, 2019) might usefully be extended to urban residential areas to promote healthier behaviours.

If the inverse association between nature visits and current smoking is causal, then targeted nature-based interventions could potentially assist individuals attempting to abstain from smoking. Current green prescribing initiatives aimed at improving mental health and physical activity (Robinson, 2021), for instance, might be extended to support individuals attempting to give up smoking.

4.4. Concluding comments

As major determinants of morbidity and mortality worldwide, smoking and alcohol misuse constitute significant public health issues. The current study provides evidence that greenspace near one's home is inversely associated with the prevalence of these two health risk behaviours within an international sample. Visiting natural spaces at least once a week, was associated with additive benefits for current smoking prevalence, but unrelated to everyday drinking. If further evidence can corroborate that these associations are causal, then improved provision and maintenance of residential greenspaces may offer a viable strategy of reducing multiple health risk behaviours at the population-level. Further, more targeted nature-based interventions may be more appropriate for individuals attempting to abstain from smoking, than those for whom alcohol misuse is an issue.

CRediT authorship contribution statement

Leanne Martin: Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Conceptualization. **Mathew P. White:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization. **Sabine Pahl:** Writing – review & editing, Supervision, Conceptualization. **Jon May:** Writing – review & editing, Supervision. **John N. Newton:** Writing – review & editing, Conceptualization. **Lewis R. Elliott:** Writing – review & editing, Project administration, Methodology, Data curation. **Marta Cirach:** Writing – review & editing, Validation, Data curation. **James Grellier:** Writing – review & editing, Project administration, Methodology, Data curation. **Gregory N. Bratman:** Writing – review & editing, Funding acquisition. **Mireia Gascon:** Writing – review & editing. **Maria L. Lima:** Writing – review & editing. **Mark Nieuwenhuijsen:** Writing – review & editing, Funding acquisition. **Ann Ojala:** Writing – review & editing, Funding acquisition. **Anne Roiko:** Writing – review & editing, Funding acquisition. **Matilda van den Bosch:** Writing – review & editing, Funding acquisition. **Lora E. Fleming:** Writing – review & editing, Project administration, Funding acquisition.

Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 666773. Data collection in California was supported by the Center for Conservation Biology, Stanford University. Data collection in Canada was supported by the Faculty of Forestry, University of British Columbia. Data collection in Finland was supported by the Natural Resources Institute Finland (Luke). Data collection in Australia was supported by Griffith University and the University of the Sunshine Coast. Data collection in Portugal was supported by ISCTE—University Institute of Lisbon. Data collection in Ireland was supported by the Environmental Protection Agency, Ireland. Data collection in Hong Kong was supported by an internal University of Exeter—Chinese University of Hong Kong international collaboration fund. We also acknowledge the support of the Economic and Social Research Council (ESRC) who funded the first author's contribution to this research through the South West Doctoral Training Partnership Placement Scheme, linked to PhD studentship funding awarded to the University of Plymouth.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2025.103479.

Data availability

The data that has been used is confidential.

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