Health & Place 85 (2024) 103175

Contents lists available at ScienceDirect

Health and Place

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

Nature visits, but not residential greenness, are associated with reduced income-related inequalities in subjective well-being

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ARTICLE INFO

Keywords:
Residential greenness
Recreational nature visits
Socio-economic inequalities
Subjective well-being
Mental health
Equigenesis

ABSTRACT

Nature exposure can promote human health and well-being. Additionally, there is some, albeit mixed, evidence that this relationship is stronger for socio-economically disadvantaged groups (equigenesis). Using a cross-sectional survey of the Austrian population ($N = 2300$), we explored the relationships between both residential greenness and recreational nature visits, and affective (WHO-5 Well-Being Index) and evaluative (Personal Well-Being Index-7) subjective well-being. Partially supporting the equigenesis hypothesis, regression analyses controlling for potential confounders found that recreational visit frequency, but not residential greenness, moderated the effect of income-related disparities in both subjective well-being metrics. Results suggest that merely making neighborhoods greener may not itself help reduce inequalities in subjective well-being. Additionally, greater efforts are also needed to support individuals from all sectors of society to access natural settings for recreation as this could significantly improve the well-being of some of the poorest in society.

1. Introduction

Prevalence of mental health issues and poor well-being is high and saw an upturn during the COVID-19 pandemic (Nochaiwong et al., 2021; World Health Organisation, 2022). Moreover, there is evidence for a clear link between low income and poorer mental health (Pieh et al., 2020; Ridley et al., 2020), creating inequalities in individual health and well-being (Tibber et al., 2022). Consequently, promoting well-being and reducing the prevalence of mental health issues, especially among those living in more deprived circumstances, is a key target of public health promotion globally (World Health Organisation, 2022).

There is growing evidence that natural green and blue environments such as parks, woodlands, rivers and lakes can contribute to these goals. Not only is nature exposure positively linked to mental health and well-being in general (Callaghan et al., 2021; Gascon et al., 2017; Hartig et al., 2014; Jimenez et al., 2021), the beneficial effects may be particularly strong for socio-economically disadvantaged groups, a so-called "equigenic" effect (Mitchell, 2013). While this effect is relatively consistent for some physical health outcomes (see Rigolon et al., 2021 for a systematic review), evidence regarding mental health and well-being has been mixed. While a few studies find that the amount of neighbourhood green and blue spaces has a moderating effect on the association between socio-economic status and mental health (i.e., reduces societal inequalities, e.g., Brown et al., 2018; Garrett et al., 2019a; McEachan et al., 2016), others find no moderating effect (Geiger et al., 2023; Sugiyama et al., 2016; Wang et al., 2022).

One possible explanation for this inconsistency is that many studies looking at the equigenic effects of nature have focused on relatively simple measures of *the amount of residential nature* people are exposed to (e.g., percentage of green vegetation within a few hundred meters of people's homes, indicated by satellite imagery, Holland et al., 2021), which only paints a very partial picture of people's actual local nature exposure. For instance, the use of such approaches says little about whether or not people can actually see, and thus possibly benefit from seeing vegetation or blue spaces from their windows (e.g., Garrett et al., 2019b; Nutsford et al., 2016), or whether the "greenness" is public or

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https://doi.org/10.1016/j.healthplace.2024.103175
Received 27 September 2023; Received in revised form 4 December 2023; Accepted 10 January 2024
Available online 23 January 2024

private in terms of physical access. Collins et al. (2023), for instance, recently demonstrated that potential access to, and use of, public parks and private gardens are differentially associated with mental health outcomes across different groups (e.g., separating by age and gender) and speculated that this is associated with the different types of activities associated with different local settings (see also de Bell et al., 2020). Since there is a premium for housing with green and blue space views (Wu et al., 2022), and private gardens (Gibbons et al., 2014), whether or not any given study shows equigenic effects may in part depend on generally uncontrolled aspects of exposure such as viewshed and the percentage of greenspaces taken up by private gardens among less wealthy residents and/or neighbourhoods.

Further, satellite imagery, and even many landcover maps that are able to differentiate between public and private greenspaces, tend to say little about the quality of these areas. This is important since several studies have shown that the nature surrounding poorer neighbourhoods is of lower quality than the nature surrounding richer neighbourhoods (Khomenko et al., 2020; Rigolon, 2016), and this might directly reduce its equigenic potential. Supporting this possibility, Wang et al. (2022) found that measures of greenspace *quantity* did not moderate the effect of socioeconomic variables on depression and anxiety scores, but measures of greenspace *quality* did. Similar patterns were observed for park attractiveness (Sugiyama et al., 2016). One reason why quality and attractiveness may be important is because they encourage more visits to local green and blue spaces (Fongar et al., 2019). Growing evidence suggests that these visits, and recreational contact with nature more generally, may be more important for mental health and well-being than neighbourhood greenness/blueness *per se* (White et al., 2021).

Importantly, this is not simply because visits mediate the relationship of residential nature and health, i.e., people who live in greener areas visit nature more and these local visits account for the benefits (e.g., Hartig et al., 2014). While this may indeed play some role (Elliott et al., 2023), there is also evidence from several European cities that median travel distances for nature visits range around 1.4–1.9 km (Elliott et al., 2015; Hillsdon et al., 2015; Schindler et al., 2022), which is well beyond the neighbourhood buffers or the 3-30-300 concept usually used to measure residential nature exposure (Holland et al., 2021; McEachan et al., 2016; Nieuwenhuijsen et al., 2022). Thus, people living in deprived areas can still gain access to more and (potentially) higher quality nature through recreational visits beyond the boundaries of their immediate neighbourhoods, which could be linked to better health and well-being. Supporting this possibility, Garrett et al. (2023) found that the effect of household deprivation on affective well-being and life satisfaction among a representative sample of the adult population in Wales was indeed moderated by weekly recreational time spent in nature (including visits near and far from home), but there was no evidence for a similar moderating, equigenic, pattern for residential greenness.

Building on this finding, the current research investigated the extent to which residential nature and recent nature visits may moderate the expected disparity in subjective well-being as a function of income among a sample of the adult population of Austria representative on age, sex, and federal state. Following Garrett et al. (2023), we predicted that income-related inequalities in subjective well-being would be smaller as a function of direct nature experiences (i.e., recreational visits) but not necessarily as a function of neighbourhood nature (i.e., residential greenness). Put simply, we assumed that the equigenic potential of nature on subjective well-being would be stronger with respect to people's recreational exposure to natural places than their exposure to the nature surrounding their home.

Austria is a landlocked country in the heart of Europe with a population of ∼9 million. Austria, and its capital Vienna (population: ∼2 million), is an interesting case study for several reasons. Forty-one percent of the total population live in rural areas, which is relatively high compared to the European Union average (25%) or the United States (17%; United Nations Population Divisions, 2022). Thus, a potential "buffering" effect of nature on socio-economic inequalities might be particularly strong in Austria due to relatively large proportions of the population, rich and poor, with high residential, and potentially also recreational, nature exposure. Any association, however weak, may thus be more detectable due to the greater equity in nature exposure among the population as a whole (Fian et al., 2023), and would go beyond focusing on urban areas and/or highly urbanized countries.

Further, in 2023, Vienna was ranked as the most 'liveable city' globally for the fourth time in five years (The Economist, 2023). Although green and blue spaces are not technically part of the index, which includes quality of healthcare, education, stability, infrastructure, culture and (other metrics of) environment, approximately half of Vienna's landcover is made up of green (45%) and blue (4.6%) spaces (MA23, 2021), which indirectly may support its "liveability". Nevertheless, as with cities elsewhere, income-related inequalities in local green space are also present in Vienna with lower coverage in lower socio-economic status (SES) neighbourhoods (Khomenko et al., 2020). However, these inequalities are, at least to some extent, counter-balanced by the highly integrated and affordable public transport system (Brenner et al., 2021), that, alongside an extensive cycling and walking infrastructure, directly facilitates access to some of the city's most important green (e.g., Prater, Vienna Woods, inner city historic gardens) and blue (e.g., Danube Island; Old Danube, Donaukanal) spaces. Thus, although there are also inequalities in direct neighbourhood nature in Vienna, opportunities for spending time outdoors slightly further afield, but still within the city's boundaries, are readily available, potentially helping to reduce inequalities. Therefore, we tested our core predictions in the Austrian sample and, in addition, in a smaller subsample of Viennese residents.

A range of health and well-being metrics have been explored previously in the literature on the equigenic potential of nature, specifically distinguishing affective, cognitive and evaluative components. Garrett et al. (2023) analysed two different measures of subjective well-being (SWB). SWB is defined as the way people think and feel about their lives, and is consistently predicted by life circumstances such as income, employment status, and health, and in turn predicts future outcomes such as health, earnings, and mortality (Diener et al., 1999). SWB has an *affective* (or hedonic) component, relating more to feelings and emotional states, and a *cognitive* component, which focuses on reflective, evaluative judgements of one's circumstances (OECD, 2013b; Office of National Statistics, 2011). Garrett et al. (2023) used the Warwick Edinburgh Mental Well-Being Scale (WEMWBS; Tennant et al., 2007) for the more affective component (example item: "I've been feeling good about myself"), and life satisfaction ("Overall, how satisfied are you with life nowadays") as the more *evaluative* component.

Another metric of affective well-being is the World Health Organisation's 5-Item well-being measure (WHO-5), which includes items very similar to the WEMWBS (example item: "I have felt cheerful and in good spirits" in the last two weeks). It was chosen here because it has been found to be sensitive to both residential and recreational exposure (White et al., 2021) as well as, crucially, nature's equigenetic potential (Mitchell et al., 2015). For measuring evaluative well-being, the Personal Well-being Index (PWI-7, International Wellbeing Group, 2013) asks how satisfied people are with seven life domains including health, relationships, and community. Given that these domains have all been considered possible beneficiaries of nature exposure (e.g., Hartig, 2021), this 7-item metric of life satisfaction based on different life domains may be more sensitive to both residential and recreational nature contact than a single-item global measure.

Thus, building on Garrett et al.'s (2023) approach and keeping study findings comparable, we used the WHO-5 and PWI-7. Using the latter was a potentially important extension of Garrett et al. (2023), as not only did they not find any moderating effect of residential greenness on the relationship between income and life satisfaction using the single global item, they also failed to find a relationship between life satisfaction and residential greenness at all (see also White et al., 2017). By using the richer, multi-domain satisfaction scale we hoped to increase the sensitivity of the evaluative well-being metric.

Positive relationships between nature exposure and subjective well-being may not be causal, instead influenced by other factors that are related to both. For instance, SWB tends to be higher in Western-European countries in early retirement than in mid-working life (Steptoe et al., 2015), and retired people experience less time pressures, one of the key reasons for not visiting nature (Boyd et al., 2018). Thus, it may be that an association between more nature visits and greater SWB is merely a byproduct of age/work status. To explore this, we used regression analyses and controlled for age, work status, and other potentially relevant covariates (Boyd et al., 2018; Lenaerts et al., 2021; Lin et al., 2014; White et al., 2018).

2. Method

2.1. Sample and procedure

Data collection for the Austrian sample used here was an extension of the BlueHealth International Survey (BIS) on green and blue space contact across multiple countries (Grellier et al., 2017), and conducted in October 2020. Data was collected online by an international market research company using established internet-panels. Full methodological details of the BIS are available on the Open Science Framework website: https://doi.org/10.17605/OSF.IO/7AZU2. Data was collected in accordance with relevant guidelines and regulations, and informed consent was obtained. Ethical approval was granted by the University of Exeter Medical School's Research Ethics Committee (Ref: Aug16/B/099).

The total Austrian sample of $N = 2514$ was stratified to be representative in terms of age, sex and federal state. Following the guidelines of the main BIS project (Elliott and White, 2020), respondents with particularly long/short survey duration, specifically the top and bottom 1% of responses (i.e., <6 min or >360 min), were excluded from the analyses *a priori* ($n = 50$). Further, cases with insufficient or missing geographical data (i.e., participants did not use the google map locator to identify where they lived, $n = 164$) were also excluded. The final analytical sample was $n = 2300$ (91.5%), including a Vienna subsample consisting of $n = 481$ participants. A comparison of the original and final samples, alongside Austrian national averages where available, is presented in Supplementary Table S1 and it shows that the final sample continued to be broadly representative of the adult Austrian population.

2.2. Measures

As with the BIS generally, the full survey asked participants a range of questions, but here we focus only on those variables of direct interest to the current study.

2.2.1. Outcomes

2.2.1.1. Affective well-being. The World Health Organisation's 5-item, Well-Being Index (WHO-5) is a common measure of recent affective well-being and used as screening tool for depression (Topp et al., 2015). Respondents are asked to consider the extent to which they experienced five feelings and thoughts over the last two weeks including: "I have felt cheerful and in good spirits"; with response options ranging from (0) *at no time* to (5) *all of the time*. Responses were summed and multiplied by 4 to result in a score out of 100 (Topp et al., 2015). Cronbach's alpha was $\alpha = 0.90$ for both the full and Viennese subsamples.

2.2.1.2. Evaluative well-being. The Personal Well-Being Index (PWI) is a 7-item scale that measures satisfaction with the following life domains: standard of living, health, life achievement, personal relationships, personal safety, community connectedness, and future security (International Wellbeing Group, 2013). Respondents are asked how satisfied they are with the respective domain on a scale from (0) *extremely dissatisfied* to (10) *extremely satisfied*. Responses were summed and averaged to derive a Personal Well-Being Index. Cronbach's alpha was $\alpha = 0.89$ for both samples.

2.2.2. Residential greenness

Participants indicated their home location via a Google Maps application programming interface. The exact location was only recorded to three decimal points (approx. 75m precision) on latitude and longitude to reduce the ability to identify individual homes. Full details of collection and processing of this data can be found in the technical report of the main BIS study (Elliott and White, 2020). Residential greenness was estimated using the Normalised Difference Vegetation Index (NDVI) with data taken from MODIS Terra satellite imagery (https://modis.gsfc.nasa.gov/). From the respondent's home location, we derived the percentage (%) of photosynthetically active vegetation in a 1000m radial buffer (which does not differentiate between public and private sources; see also Fian et al., 2023).

2.2.3. Recreational visits

In the full survey, a list of 29 green/blue spaces were presented to participants (with accompanying images). For each setting, participants were asked how often they had visited such locations for recreation in the last four weeks. Response options were: (1) *not at all*; (2) *once or twice*; (3) *once a week*; and (4) *several times a week*. For the purpose of the present study, following a similar approach used by White et al. (2021), we estimated a numerical equivalent of these response options to be zero, two, four and (a conservative) six visits in the last four weeks, respectively. Explored environments included six urban green spaces (i.e., local neighbourhood park, large urban park, community garden, playground, cemetery, botanical garden/zoo), six rural green spaces (i.e., woodland, farmland, meadow, mountain, moorland, country park), and nine inland-blue spaces (i.e., lake, urban river, rural river, waterfall, small lake/pond, wetland, outdoor public pool/thermal spa, fountain, outdoor skating rink). For the purpose of the current study, all visits were summed up and resulted in a final measure of recreational visit frequency to natural environments.

2.2.4. Equivalised income (expressed in tens of thousands of euros)

Using the same metric as that used by the European Social Survey (ESS), participants were asked to indicate their total annual household income from all sources after tax and compulsory deductions. Specifically, they could respond by indicating one of ten deciles of household income that were in line with the most recent wave of the European Social Survey administered in Austria. Additionally, there was the option to respond with "prefer not to answer". For statistical purposes, response options were recoded prior to analysis, using the median of the response range (e.g., €20,401 – €24,480 resulted in €22,440). For the highest response category (€59,521 or above), we used a conservative estimate of €59,521. To account for the differences in a household's size and composition, we calculated the equivalised income using the "OECD-modified equivalence scale" (OECD, 2013a), which attributes a weight to all members of the household (i.e., 1.0 to the first adult; 0.5 to the second and each subsequent adult; 0.3 to each child aged under 14, although in our case under 16). The equivalized net-income was then calculated by dividing the total annual household income by its equivalent size. Finally, for ease of interpreting regression coefficients, the equivalised annual household income was divided by 10,000 to represent household income in ten thousand Euros.

2.2.5. Covariates

Following previous studies (e.g., Boyd et al., 2018; Lenaerts et al., 2021; Lin et al., 2014; White et al., 2018), we controlled for sociodemographic covariates, including sex (i.e., female vs. male), age, education level (i.e., lower vs. higher, i.e., university degree), work status (i.e., in paid work vs. not in paid work), marital status (i.e., married/-cohabiting vs. not married), longstanding limiting illness, self-identified ethnicity status (i.e., ethnic minority vs. ethnic majority), presence of children in household, access to private green space (i.e., garden), access to a car, and dog ownership. Austria's nine federal states were also added as covariates. Here, sum coding was applied, comparing the mean of the dependent variable for each federal state to the overall mean of the dependent variable over all federal states. Detailed information on wording and collapsing of response categories to aid statistical analysis can be found in Table S2 in the Supplementary Materials. Given that 15.8% of respondents did not complete the income question, in order to maintain the representativeness of the sample as much as possible we also included a binary "income missing" variable, so that these participants would not be totally excluded from the models.

2.3. Statistical analysis

Primary analyses consisted of a series of six multiple linear regressions, three exploring affective well-being and three exploring evaluative well-being. The first regression for each outcome focused only on residential greenness, including an interaction term with income; the second focused only on recreational visits, again including an interaction term with income; and the third included both residential greenness and recreational visits with both income interactions. This approach allowed us to investigate the relationships between each type of nature exposure and income both independently and in combination. In order to reduce multicollinearity, core predictor variables were mean-centered before analysis. Covariates included the socio-demographic predictors listed above. Additional analyses ran the same six models for the Vienna subsample only, but due to space constraints, and the very similar findings compared to the full sample, details are presented in the Supplementary Materials, with only key descriptives and summaries included in the text below. To reduce the chance of false discovery across these multiple regressions, alpha error correction was applied using the Benjamini-Hochberg procedure (Benjamini, 1995). Although there is debate about the appropriateness of these "corrections" (Fiedler et al., 2012), given our relatively large sample, this more conservative approach reduced the chance of highlighting relatively small associations. Statistical analyses were performed using R statistical software (Version 4.2.0).

Table 1
Descriptive and correlational statistics for subjective well-being, nature exposure, and covariates in the full Austrian sample ($n = 2300$).

	Descriptives		**Correlations**				
	M	*SD*	WHO-5 [a]	PWI-7 [b]	Residential greenness [c]	Recreational visits [d]	Income in ten thousand Euros [e]
Affective well-being (WHO-5) [a]	56.83	22.70	–	.55***	.06**	.22***	.23***
Evaluative well-being (PWI-7) [b]	7.03	1.87	–	–	.04*	.15***	.31***
Residential greenness [c]	48.13	19.43	–	–	–	.15***	.02
Recreational visits [d]	26.17	17.93	–	–	–	–	.05*
Income in ten thousand Euros [e]	2.12	2.05	–	–	–	–	–
	%						
Covariates	ref	non-ref					
Income missing (*ref* = no)	19.0	81.0	.02	.05*	.03	−.02	–
Male (*ref* = female)	50.1	49.9	.05**	.01	−.03	.05*	.14***
Age group (*ref* = 18–39 years)	39.2	–	−.10***	.03	−.01	.15***	−.11***
40–59 years	–	40.5	−.00	−.08***	−.01	−.09***	.02
60+ years	–	20.3	.13***	.06**	.02	−.07***	.11***
Lower education (*ref* = higher)	23.2	76.8	−.01	−.08***	.09***	−.06**	−.13***
In paid work (*ref* = not in paid work)	46.1	53.9	.12***	.19***	.01	.05*	.29***
Longstanding limiting illness (*ref* = no)	57.3	46.1	−.29***	−.32***	−.01	−.04	−.16***
Self-identified ethnic minority status (*ref* = Ethnic majority)	90.2	–	.07***	.05**	.01	−.10***	.11**
Ethnic minority	–	6.1	−.04	−.03	−.04	.11***	−.06*
Ethnicity missing	–	3.7	−.06**	−.04*	.03	.02	−.10***
Private green space (*ref* = no)	42.9	57.1	.13***	.14***	.22***	.09***	.08***
Car access (*ref* = no)	16.9	83.1	.13***	.18***	.17***	.13***	.21***
Married cohabiting (*ref* = not married/missing)	45.8	54.2	.15***	.22***	.05*	.03	.19***
Children in household (*ref* = no)	75.9	24.1	.01	.05*	.06**	.12***	−.17***
Dog ownership (*ref* = no)	77.0	23.0	−.01	.00	.07**	.17***	−.07**
Federal state							
Vienna	20.9	–	−.06**	−.06**	−.46***	−.09***	.02
Lower Austria	21.4	–	−.02	−.01	.09***	.01	−.03
Upper Austria	18.2	–	.02	.02	.08***	.02	.04
Styria	16.0	–	.02	.01	.05**	−.04	−.05*
Tyrol	6.7	–	.05*	.06*	.13***	.05*	−.02
Carinthia	4.9	–	.05*	.03	.13***	.04*	.02
Salzburg	4.7	–	−.02	.00	.10***	.04*	.02
Vorarlberg	3.2	–	.02	−.02	.05*	.07**	.04
Burgenland	4.0	–	.00	−.01	.03	−.01	−.02

Note.
$*p < .05$. $**p < .01$. $***p < .001$.
[a] WHO-5 range: 0–100.
[b] PWI-7 range: 0–10.
[c] Green % coverage within 1000m range: 0–100%.
[d] Visit frequency score to all environments.
[e] Equivalised household income in 10,000 Euros calculated using the "OECD-modified equivalence scale", which attributes a weight to all members of the household.

3. Results

3.1. Descriptive and correlational statistics

The average residential greenness within 1000m was $M = 48.13\%$ $(SD = 19.43)$ in the Austria sample, and $M = 30.94\%$ $(SD = 18.59)$ in the Vienna subsample. The mean recreational visit frequency score (see Section 2.2.3) to natural environments in the last 4 weeks was $M = 26.17$ $(SD = 17.93)$ visits among the full sample, and $M = 22.94$ $(SD = 18.95)$ visits among the Vienna subsample. A detailed summary of descriptive and correlational statistics is shown in Table 1 for Austria, and Supplementary Table S3 for the Vienna subsample. The two metrics of subjective well-being were positively correlated, and people with greater amounts of residential greenness also tended to make more recreational nature visits at the country-level. At the country-level, both affective and evaluative well-being were positively associated with residential greenness and recreational visits. Consistent with inequality research globally, higher income was related to higher affective and evaluative well-being, and also recreational visits (in the Austrian sample) but, perhaps intriguingly, not residential greenness.

Supporting the robustness of the dataset in general, the relationships between the covariates and well-being metrics largely replicate long-standing associations reported in the literature (e.g., Dolan et al., 2008). Males reported higher affective (but not evaluative) well-being than females, adults over 60 years reported the highest well-being for both metrics, as did those in *vs.* not in paid work, those self-identifying as

Table 2
Regression models for predicting affective and evaluative well-being for the Austria sample ($n = 2300$).

	Affective well-being (WHO-5 Well-Being Index)[a]			Evaluative well-being (Personal Well-Being Index; PWI-7)[b]		
	Residential greenness[c]	**Recreational visits**[d]	**Both**	**Residential greenness**[c]	**Recreational visits**[d]	**Both**
	b (SE)	*b (SE)*	*b (SE)*	*b (SE)*	*b (SE)*	*b (SE)*
(Intercept)	44.85*** (3.27)	48.61*** (3.18)	48.54*** (3.19)	5.67*** (0.26)	5.85*** (0.26)	5.84*** (0.26)
Residential greenness	0.01 (0.03)	–	−0.02 (0.03)	−0.00 (0.00)	–	−0.00 (0.00)
Recreational visits	–	0.27*** (0.03)	0.27*** (0.03)	–	0.01*** (0.00)	0.01*** (0.00)
Income in ten thousand Euros[e]	2.86*** (0.50)	2.73*** (0.48)	2.72*** (0.48)	0.37*** (0.04)	0.37*** (0.04)	0.37*** (0.04)
Income x Residential greenness	−0.02 (0.02)	–	−0.01 (0.02)	0.00 (0.00)	–	0.00 (0.00)
Income x Recreational visits	–	−0.07*** (0.02)	−0.07*** (0.02)	–	−0.01*** (0.00)	−0.01*** (0.00)
Covariates						
Income missing (*ref* = no)						
Missing	6.47*** (1.53)	6.41*** (1.48)	6.37*** (1.48)	0.93*** (0.12)	0.93*** (0.12)	0.94*** (0.12)
Sex (*ref* = female)						
Male	0.43 (0.90)	−0.09 (0.87)	−0.12 (0.87)	−0.10 (0.07)	−0.12 (0.07)	−0.12 (0.07)
Age (*ref* = 18–39 years)						
40–59 years	3.03* (1.02)	4.41*** (1.00)	4.41*** (1.00)	−0.30*** (0.08)	−0.24** (0.08)	−0.24** (0.08)
60+ years	11.15*** (1.40)	12.25*** (1.36)	12.28*** (1.36)	0.28* (0.11)	0.32** (0.11)	0.33** (0.11)
Education (*ref* = higher)						
Lower	0.85 (1.06)	1.74 (1.03)	1.76 (1.03)	−0.08 (0.09)	−0.04 (0.08)	−0.03 (0.08)
Work status (*ref* = not in paid work)						
In paid work	3.31** (1.05)	3.20** (1.02)	3.22** (1.02)	0.34*** (0.08)	0.33*** (0.08)	−0.33*** (0.08)
Longstanding limiting illness (*ref* = no)						
Yes	−11.78*** (0.94)	−11.79*** (0.91)	−11.78*** (0.91)	−0.87*** (0.08)	−0.87*** (0.07)	−0.87*** (0.08)
Self-identified ethnicity (*ref* = Ethnic majority						
Ethnic minority	0.41 (1.86)	−1.64 (1.81)	−1.64 (1.81)	−0.04 (0.15)	−0.13 (0.15)	−0.13 (0.15)
Ethnicity missing	−2.38 (2.38)	−2.93 (2.30)	−2.92 (2.30)	−0.04 (0.19)	−0.09 (0.19)	−0.08 (0.19)
Private green space (*ref* = no)						
Yes	2.26 (0.99)	1.83 (0.96)	1.87 (0.96)	0.18 (0.08)	0.17 (0.08)	0.17 (0.08)
Car access (*ref* = no)						
Yes	1.05 (1.31)	−0.38 (1.27)	−0.36 (1.27)	0.26* (0.10)	0.19 (0.10)	0.19 (0.10)
Marital status (*ref* = not married/missing)						
Married/cohabiting	2.24 (0.97)	2.54* (0.94)	2.55* (0.94)	0.45*** (0.08)	0.47*** (0.08)	0.47*** (0.08)
Children in household (*ref* = no)						
Yes	1.80 (1.11)	0.78 (1.08)	0.79 (1.08)	0.16 (0.09)	0.11 (0.09)	0.12 (0.09)
Dog ownership (*ref* = no)						
Yes	0.80 (1.06)	−1.06 (1.04)	−1.06 (1.04)	0.03 (0.08)	−0.05 (0.08)	−0.04 (0.08)
Federal state						
Vienna	−1.61 (1.18)	−0.81 (1.04)	−1.08 (1.14)	−0.07 (0.09)	−0.01 (0.09)	−0.04 (0.09)
Lower Austria	−0.28 (1.07)	0.09 (1.03)	0.09 (1.03)	0.02 (0.09)	0.04 (0.08)	0.04 (0.08)
Upper Austria	−2.20 (1.02)	−1.76 (0.99)	−1.77 (0.99)	−0.06 (0.08)	−0.04 (0.08)	−0.04 (0.08)
Styria	0.46 (1.12)	1.23 (1.09)	1.22 (1.09)	0.06 (0.09)	0.09 (0.09)	0.09 (0.09)
Tyrol	3.83 (1.60)	3.04 (1.55)	3.13 (1.56)	0.42** (0.13)	0.37** (0.13)	0.38** (0.13)
Carinthia	2.75 (1.85)	2.31 (1.78)	2.41 (1.79)	0.13 (0.15)	0.10 (0.15)	0.11 (0.15)
Salzburg	−3.08 (1.87)	−3.65 (1.81)	−3.57 (1.81)	−0.06 (0.15)	−0.09 (0.15)	−0.08 (0.15)
Vorarlberg	1.71 (2.22)	0.23 (2.16)	0.28 (2.16)	−0.25 (0.18)	−0.30 (0.18)	−0.31 (0.18)
Burgenland	−1.58 (2.03)	−0.67 (1.96)	−0.72 (1.97)	−0.19 (0.16)	−0.15 (0.16)	−0.15 (0.16)
R^2	.162	.213	.213	.208	.225	.225
Adj. R^2	.153	.205	.204	.199	.216	.216

Note. $N = 2300$.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.
[a] WHO-5 range: 0–100.
[b] PWI-7 range: 0–10.
[c] Green % coverage within 1000m range: 0–100%.
[d] Visit frequency score to all environments.
[e] Equivalised household income in 10,000 Euros calculated using the "OECD-modified equivalence scale", which attributes a weight to all members of the household. Table shows unstandardised coefficients (*b*).

belonging to an ethnic majority *vs.* ethnic minority or not reporting ethnicity, those with *vs.* without a private greenspace, those with *vs.* without a car, and those married/cohabiting *vs.* those living alone. Those with *vs.* without a longstanding limiting illness reported lower well-being on both metrics, those with lower *vs.* higher education, and those with no *vs.* some children in the household reported lower evaluative but not affective well-being, and dog ownership was not associated with either metric. People in Vienna reported lower well-being for both metrics, in Tyrol higher for both, and in Carinthia higher for affective well-being.

3.2. Main analyses

Regression models can be found in Table 2 for the full Austrian sample, and Supplementary Table S4 for the Vienna subsample. As can be seen for each outcome variable in the rightmost column of Table 2, including both moderator variables and interaction terms simultaneously did not result in any significant changes in results. Therefore, these results are not presented separately in the text. Additionally, Fig. 1 (and Supplementary Fig. S1 for the Vienna subsample) visualise the interaction effects.

3.2.1. Affective well-being (WHO-5 Well-Being Index)

3.2.1.1. Residential greenness. Consistent with Garrett et al. (2023), and the tentative suggestion that the direct living environment may be less important than recent activities for affective well-being, residential greenness was not significantly linked to affective well-being in the regression analyses. Further replicating Garrett et al. (2023), and contrary to the equigenesis hypothesis, there was also no interaction between income and residential greenness.

3.2.1.2. Recreational visits. There was a significant positive association between recreational visits and affective well-being ($b = 0.26, p < .001$). Moreover, the interaction between recreational visits and income was also significant ($b = -0.07$, $p < .001$). Supporting an equigenic hypothesis, the difference in well-being as a function of income was smaller for those who visited nature frequently. Moreover, the interaction was significant for recreational visits but not residential exposure, supporting our central prediction, that equigenic effects would be stronger with respect to visits than merely neighbourhood exposure. The contrasting results are presented graphically on the left of Fig. 1. (Note: For ease of interpretation, figures show non-mean-centered predictor variables.)

3.2.2. Evaluative well-being (personal Well-Being Index; PWI-7)

3.2.2.1. Residential greenness. Similar to the findings for the WHO-5, regression results controlling for potential confounders found no significant relationship between residential greenness and evaluative well-being. This replicates Garrett et al. (2023), even though we used an arguably more sensitive 7-item metric of the same underlying construct. Crucially, for the equigenesis hypothesis, and again supporting Garrett et al. (2023), we found no interaction between residential greenness and income.

3.2.2.2. Recreational visits. Consistent with the affective well-being model, more nature visits were also related to higher evaluative well-being ($b = 0.01$, $p < .001$), and the interaction between income and recreational visits was also significant ($b = -0.01, p < .001$). Again, our results provide support for an equigenic effect of visiting nature but not living near nature. Findings are illustrated graphically on the right of Fig. 1.

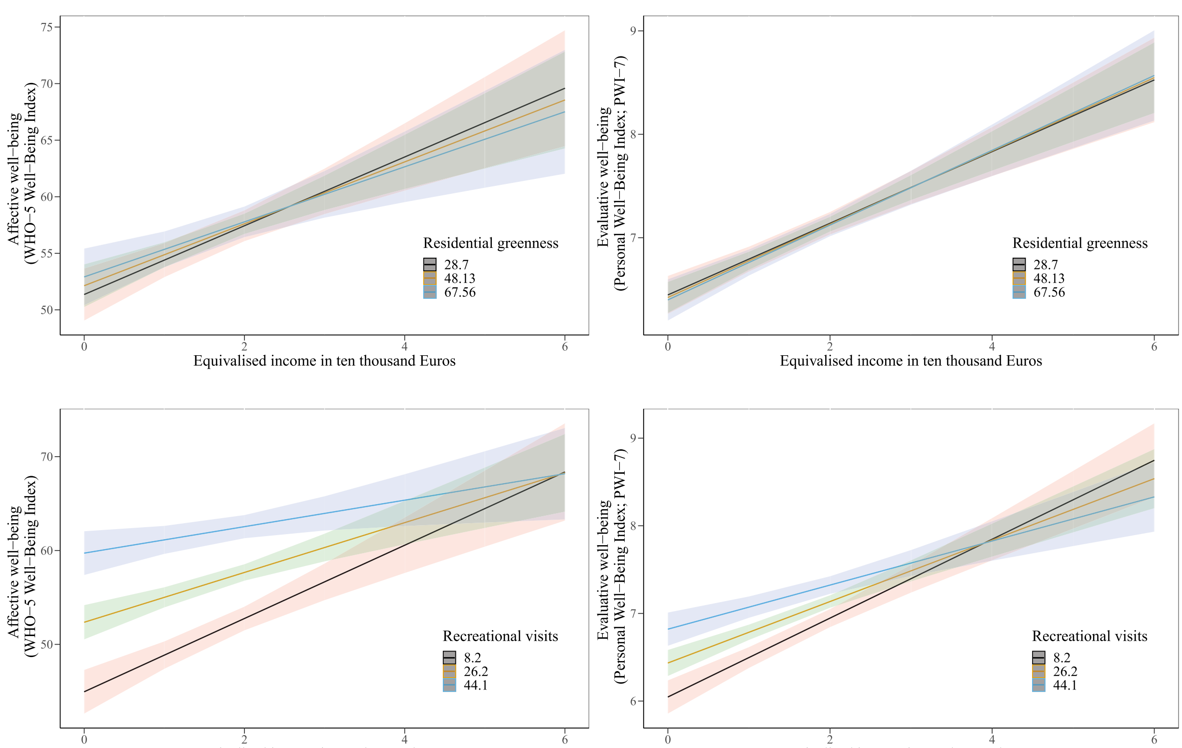

Fig. 1. Interaction effects for the Austria sample (Income x Residential greenness at the top; Income x Recreational visits at the bottom; Affective well-being on the left; Evaluative well-being on the right).
Note. $N = 2300$. WHO-5 range: 0–100. PWI-7 range: 0–10. Residential greenness = NDVI (green % coverage within 1000m range: 0–100%). Recreational visits = visit frequency score to all environments. Equivalised household income in 10,000 Euros calculated using the "OECD-modified equivalence scale", which attributes a weight to all members of the household.

3.2.3. Covariates

Results for covariates were largely in-line with previously observed patterns in subjective well-being research (Dolan et al., 2008). People in paid work *vs.* not in paid work, those who were married/cohabiting *vs.* single/separated/divorced, and those without *vs.* with a long-term limiting illness reported more positive affective and evaluative well-being. The results for age were slightly more complicated (though also in-line with previous findings) with an approximately linear function for affective well-being but a U-shaped function for evaluative well-being (Steptoe et al., 2015). Perhaps more interesting in the present context, having access to private greenspaces was not associated with either affective or evaluative well-being, but living in the Tyrol region was associated with greater evaluative well-being than the average across the whole of Austria. Finally, people who did not report their income also reported significantly higher affective and evaluative well-being than those who did report their income.

3.3. Additional analysis of Vienna subsample

The pattern of results was very similar for the Vienna subsample (with larger confidence intervals due to the smaller sample). For full results, see Supplementary Table S4 and Supplementary Fig. S1. There were no significant relations between either affective or evaluative well-being and residential greenness, and again no interaction between residential greenness and income for either outcome. Recreational visits were, however, again positively associated with both affective ($b = 0.27$, $p = <.001$) and evaluative well-being ($b = 0.01$, $p = .010$), and, supporting the equigenisis hypothesis for this urban subsample, the interactions between income and recreational visits were also both significant (affective well-being: $b = -0.10$, $p = .014$; evaluative well-being: $b = -0.01$, $p = .004$).

4. Discussion

Despite considerable policy interest in the potential of green and blue spaces to mitigate income-related inequalities in mental health and well-being (World Health Organisation, 2017), research supporting this so-called equigenesis effect is mixed (e.g., Garrett et al., 2023; Geiger et al., 2023). In part, inconsistent findings may be due to the use of different exposure and well-being metrics, and different populations across studies. To address this issue, and following Garrett et al. (2023), the current study explored the relationships between both residential greenness and recreational nature visits, and affective and evaluative well-being, and the degree to which all four of these relationships might be moderated by household income. Extending previous research, we used: 1) a globally recognised metric of affective well-being (the WHO-5), 2) a multi-dimensional measure of evaluative well-being (PWI-7) in order to increase sensitivity to possible effects, and 3) data from both an entire country (Austria) and a major urban centre (Vienna) to explore both urban and relatively rural populations.

Replicating earlier work on income-related inequalities and well-being (e.g., Dolan et al., 2008), people living in wealthier households were generally happier, calmer and more relaxed in the last two weeks (WHO-5), and overall more satisfied across a range of life domains (PWI-7). Replicating previous nature and mental health research (e.g., Callaghan et al., 2021; Triguero-Mas et al., 2017; Wang et al., 2019), unadjusted results also showed people had higher affective and evaluative well-being if they lived in greener neighbourhoods and visited nature more often. These results were mostly found for both Austria as a whole and urban Vienna residents (for Vienna, no links between residential greenness and well-being were found).

However, after controlling for income and other potential confounders, the relationships between residential greenness and both well-being metrics became non-significant. People living in wealthier households seem happier and more satisfied with their life circumstances for other reasons. The positive relations between nature visit frequency and both affective and evaluative well-being did, however, remain significant when controlling for confounders. As predicted though, relationships between visit frequency and both well-being outcomes were moderated by income. Put simply, well-being was high among those in higher income households regardless of nature visit frequency whereas the relationship with well-being and nature visits became stronger as household income decreased. This pattern is clearly shown for both Austria as a whole (Fig. 1) and the Vienna subsample (Fig. S1).

All key findings replicate those of Garrett et al. (2023) in a different country using different metrics of residential and visit exposure, and different metrics of affective and evaluative well-being, and are robust to whole country and urban only contexts. That we even replicated the non-significant association between residential greenness and evaluative well-being using a potentially more sensitive seven-item, as opposed to a one-item satisfaction measure (Garrett et al., 2023), reduces the possibility that the earlier finding was due to the specific measure used. Overall, and as predicted, in terms of reducing income-related inequalities in subjective well-being, recreational visits (i.e., what people did) appeared more important than residential greenness (i.e., where they lived). Importantly, this is not to question the importance of quality greenspaces near people's homes, but it does highlight the importance of actually using these spaces for well-being.

Given the previously inconsistent findings with respect to nature's equigenic potential (e.g., Brown et al., 2018; Garrett et al., 2019a; McEachan et al., 2016; Mitchell et al., 2015; Mitchell and Popham, 2008; Rigolon et al., 2021; Sugiyama et al., 2016; Wang et al., 2022), the degree of consistency between the two studies is perhaps surprising, especially given the differences in the data collected. Garrett et al. (2023), for instance, arguably used a more sensitive nature exposure metric, i.e., the Enhanced Vegetation Index (instead of NDVI) and minutes in nature per week (instead of visits in the last four weeks), whereas we used arguably more robust well-being metrics (WHO-5 instead of WEMWEBS; and PWI-7 instead of life satisfaction). The results seemed robust to these differences. Nonetheless, the data also shares some commonalities. Both studies used self-report survey data from representative samples in relatively small, rural countries which might share certain characteristics in nature, nature accessibility, population type, and levels of well-being that are not immediately generalisable to other contexts. However, the Vienna subgroup seems more comparable to most previous research with regard to sample characteristics, and here we found a very similar pattern in terms of equigenic potential of nature visits in the urban setting.

How large/meaningful were the key associations? The current work suggests that one extra nature visit in the last four weeks was associated with a 0.27% increase in affective well-being. Considering the recommendation to spend at least 120 min a week in nature (White et al., 2019), this could be transferred to 3 weekly visits of 40 min, resulting in 12 more visits over the course of 4 weeks and, thus, an increase of just above 3% in well-being. While this may not sound much, it is comparable to the higher levels of well-being seen for being in paid work vs. not in paid work (3.2%), and being married/cohabiting vs. not (2.6%). Thus, regular nature visits may be as important for well-being as some socio-demographic factors widely considered important for subjective well-being.

Our results also suggest that at a country level, income-related inequalities in residential greenness are not as pronounced in Austria as they are elsewhere (a similar pattern has been found for blue spaces; Fian et al., 2023). Nevertheless, higher income was related to more frequent nature visits and this, in turn, was linked to higher well-being. This might pose several issues with respect to health inequalities. First, higher-income individuals are more likely to have a greater range of options for accessing natural spaces, potentially with higher restorative qualities, like e.g., mountainous areas (Arnberger et al., 2018), for instance because of enhanced mobility due to availability of a private car (Morris et al., 2020) or due to higher costs associated with visiting certain environments. In Austria, this was previously found for visits to lakes and small water bodies that were visited more by the highest income groups (Fian et al., 2023). Second, lower income may be linked to longer working hours to obtain a living wage and less time available for recreational time spent in nature (Boyd et al., 2018). Considering the greater beneficial potential of nature visits for low *vs*. high income individuals, this highlights the importance of promoting recreational time outdoors, especially for this group. This could include land management or planning policies and the provision and accessibility of safe and high-quality green/blue space in deprived communities as well as interventions to encourage actual use, e.g., nature-based education (NBE) in low-income schools (Sprague and Ekenga, 2022), or gatekeeper systems to reduce access barriers for immigrant communities (Höglhammer et al., 2019). Future research could further explore the specific causal mechanisms between nature exposure and well-being as well as characteristics of natural environments that have the greatest potential in buffering health inequalities.

The potential robustness of our key results is supported by the familiar pattern of relationships between several covariates and both affective and evaluative wellbeing (Dolan et al., 2008). The slightly more complicated findings for age highlight that affective and evaluative well-being are not identical constructs. According to Kahneman and Riis (2005), evaluative well-being is “thinking about” one’s life, while affective well-being is the “lived experience” of one’s life and these can diverge. For instance, one can feel quite happy on a day-to-day basis (an affective assessment), but still feel a sense that life could be better (an evaluative judgment).

Finally, that people who did not report their income also reported significantly higher affective and evaluative well-being than those who did, suggests that non-reporting of income was not random, instead being more likely to occur among people with higher household incomes, a finding consistent with neighbouring Germany (Frick and Grabka, 2014). This has potentially important implications for our results and their interpretation. For instance, we found no significant correlation between income and residential greenspace despite studies (including those conducted in Austria) generally finding greater greenspace around homes of wealthier individuals (Khomenko et al., 2020). If, as we suspect, those who did not report their income are both wealthier and live in greener areas, then this would have reduced the strength of the overall correlation in line with the non-significant relationship here. Further, our moderating, equigenic, analyses need to be treated with caution until further research is conducted which is able to ensure representative analytical samples (i.e., those from all income groups). For instance, if those not declaring their income were the richest then the income-wellbeing slopes might be steeper (given the positive income missing coefficients), and this may reduce the interaction effect seen for visits. Although this is speculation based on less than 20% of the sample, it appears important enough to warrant caution.

We also recognise several other limitations of our study. Due to the cross-sectional nature of the data, we remain cautious about assuming causality between spending time in nature and better well-being. It could instead be argued that individuals with higher well-being spend more time in nature anyway, compared to those with poorer well-being, who may, for instance, be reluctant to leave the house. There are at least two reasons for doubting that this alternative account can explain all of the findings. First, there are several longitudinal studies, including a recent one with over 2.3 million adults across a 10-year time period which shows that mental health is supported by greater green space exposure over time (e.g., Geary et al., 2023). Second, research related to the current survey across 18 countries found that people taking medication for depression visited nature just as often as people without depression, and that people taking anxiety-related medication visited significantly more often than those not on mediation (Tester-Jones et al., 2020), which makes it unlikely that our results are solely a reflection of people with poorer mental health being less likely to visit nature.

As noted in the introduction, measures of greenspace such as that used here (the NDVI) are unable to capture important explanatory exposure pathways such as visual amenity, public vs. private access and quality, with the latter at least having been shown to matter in terms of equigenic potential on an urban level (Wang et al., 2022). By themselves, therefore, our results do not rule out the possibility that local greenness may still have equigenic potential, even in Austria, though further exploration of this possibility would require more extensive household (i.e., views) and neighbourhood (i.e., gardens) data than we had access to. Moreover, we only looked at recreational visits to nature, and were unable to control for an individual’s propensity to engage in recreational activities away from the home in general. Many other recreational activities also have positive effects on well-being (e.g., sports, culture, etc.; Fujiwara et al., 2014), and our results may merely suggest that being generally active outside the home is key. Although a wealth of experimental evidence would suggest that exposure to nature does confer benefits (although see Browning et al., 2021 for a discussion of potential publication bias), future research would benefit from more direct comparisons with other potential uses of an individual’s time, especially within home vs. outside home activities (e.g., White and Dolan, 2009), or at the very least controlling for an individual’s propensity to “get out and about” in order to reduce the possibility that we are over-interpreting the specific benefits of nature-based recreation.

Much of our data is also self-report, which is possibly linked to recall or social desirability biases, and recruitment through a paid online-panel might also have caused some selection bias, e.g., by excluding people without internet access. Further, although we included several indicators of SES, such as equivalised income, education, work status, ethnicity, car ownership and access to private outdoor green space, we did not include other indicators such as social class or occupational complexity (e.g., Darin-Mattsson et al., 2017). Nor were we able to include area-level metrics of deprivation which would be important to consider in future research, especially given that more deprived areas tend to have less and poorer quality greenspaces even in Austria (Khomenko et al., 2020). We acknowledge, for instance, that a mean NDVI of 0.31 among our Vienna subsample was lower than reported previously (e.g., Barboza et al., 2021 found 0.47 in Vienna), suggesting that our sample may not have been representative of all parts of the city. Further, area-level data would improve our understanding of these relationships.

5. Conclusion

In conclusion, our study contributes to the body of literature on the equigenic potential of nature, and suggests that the association between income and affective and evaluative well-being is moderated by nature visit frequency. The relationships between income and well-being were not moderated by residential greenness. These results were found at both the whole country-level (Austria) and city-level (Vienna). In other words, what people do appears to be a more proximate and relevant factor than where they live. Policy targets and measures promoting access to, and use of, natural environments for all parts of society, particularly for socio-economically disadvantaged groups (e.g., Sustainable Development Goal 11.7), may thus play an important role in achieving public health goals.

Funding

This project received support from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 666773 (BlueHealth), the EU’s Horizon Europe research and innovation programme under grant agreement No. 101081420 (RESONATE), and the Vienna Science and Technology Fund (WWTF) through project ESR20-011. The funders had no role in the conceptualisation, design, analysis, decision to publish or preparation of the manuscript.

CRediT authorship contribution statement

Leonie Fian: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Mathew P. White:** Conceptualization, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. **Arne Arnberger:** Conceptualization, Writing – review & editing. **Thomas Thaler:** Conceptualization, Funding acquisition, Writing – review & editing. **Anja Heske:** Writing – original draft, Writing – review & editing. **Sabine Pahl:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank Lewis Elliott (University of Exeter) for support with data collection, preliminary analysis and advice, and Tytti Pasanen (Finnish Institute for Health and Welfare) for support and advice with analysis.

Appendix A. Supplementary data

Supplementary data to this article can be found online at:https://doi.org/10.1016/j.healthplace.2024.103175.

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