Original article DOI: 10.2478/aiht-2018-69-3166

Residential green and blue space associated with better mental health: a pilot follow-up study in university students

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[Received in July 2018; Similarity Check in July 2018; Accepted in November 2018]

Previous research has suggested that natural urban environment (green space and blue space) benefit mental health, but only a few longitudinal studies have explored the underlying mechanisms. In this pilot study we aimed to examine mechanisms/variables mediating associations between residential green/blue space and symptoms of anxiety/depression in 109 Bulgarian students from Plovdiv university. The students were followed from the beginning to the end of the school year (October 2017 to May 2018). Residential green space was defined as the mean of the normalised difference vegetation index (NDVI) in circular buffers of 100, 300, and 500 m around their residences. Blue space was assessed based on its presence in the same buffers. Levels of anxiety/depression were assessed using the 12-item General Health Questionnaire. The investigated mediator variables included residential noise (L_{Aeq}) and air pollution (NO_2), environmental annoyance, perceived restorative quality of the neighbourhood, neighbourhood social cohesion, physical activity, and sleep disturbance. Cross-sectional data (obtained at baseline) showed that higher NDVI correlated with better mental health only indirectly through higher physical activity and restorative quality. Longitudinal (follow-up) data showed improved mental health but no significant effect of mediator variables. Similarly, blue space correlated with better mental health in all models, but physical activity and restorative quality were significant mediator variables only in the cross-sectional analysis. Our findings support that green space and blue space are psychologically restorative features in urban environment. Future research should replicate these findings in the general population and employ longitudinal modelling tailored to the specific mechanisms under study.

KEY WORDS: *anxiety; depression; greenness; mediation modelling; water*

Common mental disorders (CMDs) include generalised anxiety disorder, depression, panic disorder, obsessive-compulsive disorder, post-traumatic stress disorder, and simple phobias; they do not affect cognition or insight as much as psychotic disorders like schizophrenia (1-3) but may still lead to considerable social and economic losses (4). Although their prevention should be among the priorities of public health care, mental healthcare systems are underfunded, especially in less affluent countries (5). Bulgaria has not set up clear regulations for psychiatric care (6) and management of CMDs in young people (7, 8). According to a national survey in 2016–2017, around 3 % of Bulgarians aged 18 to 29 years perceive their mental health as less than good (9). Given that young adulthood is associated with a high burden of mental disorders (10, 11), investigation of new preventive approaches is warranted.

In addition to genetic and social correlates of mental disorders (12), recent years have seen increasing evidence that residential green space (general vegetation level as well as structured green areas like parks) and blue space (bodies of water such as seas, lakes, and rivers) are beneficial for mental health (13, 14). The beneficial effect of green space is associated with three major domains: it reduces harmful exposures (e.g. to noise and air pollution), restores mental capacities (e.g. attention and stress recovery), and favours building new ones (e.g. social cohesion and physical activity) (15). The same mechanisms may apply to blue space (16, 17). However, the evidence of the mechanisms underlying the effects of green/blue space is thin and sometimes conflicting (17-23). In addition, concerns have been voiced about the validity of the methods used to test these mechanisms. Previous studies treated them as independent of each other, while they may be intertwined (24, 25). What is more, almost all evidence of these mechanisms is cross-sectional, and mediation modelling with cross-sectional data may indicate a significant indirect effect even if the true longitudinal indirect effect is null (26-28). The direction of the causal relationship between mental health and mediator variables is also unclear. For example, while it is assumed that noise annoyance leads to poor mental health, it may also be true that people with high levels of anxiety/depression may be more sensitive to noise (29). An incorrect analysis model setup could therefore lead to bias and inadequate prevention (24). For instance, if physical activity and social cohesion are in reality important anxiety/depression prevention mechanisms but are not identified as such, urban greening campaigns may focus on

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other functions of green space, such as reduction of air pollution, and neglect "green physical activity". Given the above limitations of previous research and the need to replicate their cross-sectional findings, this pilot longitudinal study aimed to test the theoretical assumptions linking residential green and blue space to symptoms of anxiety/depression among Bulgarian university students. According to expert recommendations (15), we tested a set of mediator variables pertaining to the three major domains of mechanisms outlined above.

PARTICIPANTS AND METHODS

Study design and sampling

This study included 109 students aged between 18 and 35 years of the Medical University in Plovdiv, the second largest city in Bulgaria. Another inclusion criterion was that they were familiar with their environment, which means that they had to be residents of the Plovdiv Province for at least six months. We targeted students of different ethnic and cultural background, age, and programme enrolment to ensure sufficient variation of the data. From the 720 eligible participants with available geographic data at baseline, we excluded those who moved to a different address during the study, who were lost to follow-up, and those who did not want to participate.

The students were asked to complete a questionnaire with questions on sociodemographic factors, residential environment, mental health, and current living address, which was needed to assess the green space and blue space in their neighbourhood. Students answered the questionnaire twice: first at the beginning of the school year in October 2017 (baseline) and then at its end in May 2018 (follow-up). Residential and sociodemographic factors were assessed once, at baseline, while all other factors were measured at both baseline and follow-up.

The study adhered to the Declaration of Helsinki and was approved by the Ethics Committee of the Medical University of Plovdiv (24). The participants gave informed consent to participate in the study. No incentives were offered.

Mental health assessment

Symptoms of anxiety/depression during the previous month were assessed with the 12-item General Health Questionnaire (GHQ-12) (30) in Bulgarian (31, 32); GHQ-12 was previously used in studies on green space/traffic noise and mental health (14, 25). It is a validated and reliable screening tool for non-psychotic mental disorders in youth (33, 34). Each item is scored from 0 to 3, and the score for this measure is the mean of item scores. Higher score denotes poor mental health. We analysed the GHQ-12 measure as a continuous variable to better use the information from the responses of our relatively small sample.

Green space and blue space assessment

Based on literature reports and our earlier research (24), we decided to use the normalised difference vegetation index (NDVI) (35) as a measure of surrounding green space. In addition, preliminary analyses of the data at baseline indicated that NDVI had the strongest association with GHQ-12. NDVI values range from -1 to +1, and positive values closer to 1 indicate high vegetation level (36). NDVI was derived from six Sentinel 2 MultiSpectral Instrument (37) satellite images with a resolution of 10 by 10 m, obtained on 16 and 18 October 2017. In line with previous studies that analysed the effects of green space and blue space separately (17, 23), we removed all water pixels from the satellite images with OpenStreetMap (OSM, OpenStreetMap Community, Cambridge, UK) water layer before determining NDVI. Mean NDVI values were extracted in circular buffers (or zones) within 100, 300, and 500-metre radius around participant's residence.

As for the participants' exposure to residential blue space, our assessment was based on its presence in the same buffers. For these calculations, we extracted data on all types of freshwater bodies and wetlands from Urban Atlas 2012 (38). For geographic data management and calculations we used the ArcGIS 10.3-10.4 geographical information system (Esri, Redlands, CA, USA).

Mediator variables

The mediator (or intervening) variables included residential noise and air pollution and annoyance from environmental pollution [rated on a scale from 0 (not at all) to 4 (extremely)], perceived restorative quality of the neighbourhood (0 to 10), neighbourhood social cohesion (0 to 6), physical activity during commuting/leisure time, and sleep disturbance (0 to 10). They were selected based on expert recommendations (15) and our previous research (24). The participants were instructed to think of the area within a 10 to 15-minute walk around their residence. All questions referred to the previous month.

The residential diurnal average noise level (L_{Aeq}) was obtained by applying a land use regression (LUR) model to the participant's residential address. The LUR model has an adjusted R^2 of 0.72 and leave-one-out cross validation R^2 of 0.65. More details about the model have been reported elsewhere (17). Nitrogen dioxide (NO_2) was employed as a proxy for residential air pollution. NO_2 was calculated using the LUR model with an adjusted R^2 of 0.52 and a root-mean-square error of 4.8 ppb (9.02 μg m^{-3}) (39). The predicted L_{Aeq} and NO_2 values outside the observed range of the measurements used to construct respective LURs were recoded to the closest observed value.

Environmental annoyance was assessed with four items asking about annoyance due to traffic, other neighbourhood noise sources, air pollution, and vibration (25). The mean of responses served as a measure of annoyance in the living environment (17).

Perceived restorative quality of the neighbourhood was assessed with two items from the Perceived Restorativeness Scale (PRS) (40, 41), which stems from the attention restoration theory (42, 43). Consistent with the previous studies (24, 25), we used only the "Being away" and "Fascination" subscales. These two factors were measured with single items to reduce response burden (44, 45). Higher mean value of these two items indicates greater restorative quality of the participant's residential environment.

Perceived neighbourhood social cohesion was measured with three items from the short version of the Perceived Neighborhood Social Cohesion questionnaire (PNSC-BF) (46, 47). Higher mean score indicates greater perceived neighbourhood social cohesion (17).

The participant's physical activity was measured with the Short Questionnaire to Assess Health-Enhancing (SQUASH) Physical Activity (48, 49). It asked about different types of physical activity performed during an average week in the past month and the time and effort it took. We assigned metabolic equivalents to commuting and/or leisure time spent walking and cycling according to their intensity and calculated total daily physical activity energy expenditure (49).

Self-reported sleep disturbance was measured by averaging responses to two items: difficulty falling asleep and waking up at night (17).

Confounding factors

At baseline, we collected data on the participant's age, gender, ethnicity, duration of residence, average time spent at home a day, and perceived economic status (0 to 5). Detailed description of these items has been reported elsewhere (17).

Statistical analysis

Because less than 10 % of values were missing from each variable, those values were replaced with those obtained with the expectation-maximisation algorithm. Given that parametric tests are fairly robust against violations of the normal distribution assumption (50, 51), most mediators were not transformed. Still, physical activity was cube root-transformed to achieve closer-to-normal distribution. Interrelations between the variables were examined with the Pearson correlations. Paired-sample *t*-test was used to assess changes in GHQ-12 and the mediator variables during the follow-up in May 2018.

For the main analysis, we first specified cross-sectional single mediation models, in which NDVI and blue space were related to GHQ-12 through L_{Aeq}, NO_2, environmental annoyance, restorative quality, social cohesion, physical activity, and sleep disturbance. The mediator variables were tested one at a time. All these variables were measured at baseline. Bias-corrected bootstrapping (5000 samples) was used to construct the 95 % confidence interval for indirect effect.

Next, longitudinal mediation was tested using cross-lagged panel mediation models, which are appropriate for only two measurement points (52). More specifically, we tested whether baseline NDVI and blue space predicted GHQ-12 at follow-up through mediator variables measured in May 2018. At the same time, the model controlled for the baseline measurements of mediator variables and GHQ-12 to separate stable variance that could not be explained by NDVI and blue space. These baseline measurements were entered as covariates (52) (Figure 1). The logic was that if NDVI and blue space at baseline could explain variations in GHQ-12 at follow-up through mediator variables at follow-up above and beyond the variation explained by GHQ-12 and mediator variables at baseline,

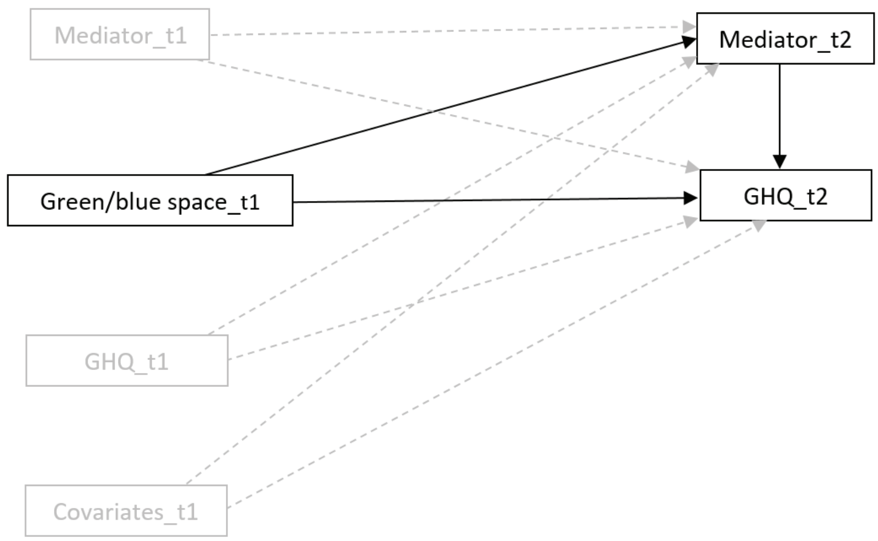

Figure 1 *Statistical diagram of a longitudinal cross-lagged panel mediation model. GHQ – General Health Questionnaire, dependent variable; Green/blue space – independent variable; Mediator variables – restorative quality, physical activity, environmental annoyance, sleep disturbance, social cohesion; t1 – variable measured at baseline, t2 – variable measured at follow-up*

then NDVI and blue space accounted for some change in GHQ-12, and were likely its causal predictors (53, 54).

For modelling we used the PROCESS macro v. 2.16 (54) for IBM SPSS Statistics for Windows v. 21.0. (IBM Corporation, Armonk, NY, USA).

The results were considered statistically significant at the p<0.05 level (two-tailed). Mediation was confirmed if the indirect effect through the mediator significantly exceeded zero, regardless of the significance of the total effect (direct + indirect) (55).

RESULTS AND DISCUSSION

Table 1 shows the participants' sociodemographic characteristics. Table 2 shows the correlation matrix and descriptive statistics of the main variables. The only significant change in mean scores on self-reported variables was observed for physical activity, which was lower at follow-up (data not shown). NDVI and blue space had a stronger correlation with lower GHQ-12 scores (better mental health) at follow-up. Conversely, their correlation with mediator variables was stronger at baseline. GHQ-12 scores and mediator variables also correlated better at baseline.

Table 3 shows the results of the mediation models. In the cross-sectional analysis, NDVI did not directly correlate with GHQ-12, but it was indirectly associated with lower GHQ-12 through higher physical activity and restorative quality. Interestingly, in the longitudinal analysis, higher NDVI significantly correlated with lower GHQ-12, but none of the indirect effects was significant.

Living close to blue space (<300 m) was associated with lower GHQ-12 in both the cross-sectional and longitudinal analyses. As with NDVI, the mediator variables linking blue space to lower GHQ-12 were higher physical activity and restorative quality, but only in the cross-sectional analysis. Results for green/blue space were mostly consistent across different buffers.

General discussion

Our cross-sectional mediation models have confirmed that higher green space correlates with better mental health indirectly, through higher physical activity and restorative quality. The longitudinal analysis has also shown that higher green space may improve mental health, but we found no evidence of mediation through the above mediator variables. Blue space also correlated with improved mental health in all models, but physical activity and restorative quality mediated this association only in the cross-sectional analysis.

Contact with nature containing vegetation or bodies of water may have neuroprotective effects against anxiety or depression. Kühn et al. (56) reported a correlation between the proportion of green space around participants' residence and the volume of grey matter in the amygdala. Another recent study in children evidenced a correlation between the volume of some brain structures and NDVI within 100 m around the residence (57). Tang et al. (58) exposed volunteers to images of urban and natural landscapes during brain magnetic resonance imaging sessions and found higher activation in regions associated with directed attention (which may exhaust cognitive faculties) when exposed to the urban landscape images than to natural (water) images. In addition to restoring attention and enhancing stress recovery, urban nature may promote social cohesion and physical activity by encouraging people to spend more time outdoors. In turn, social contacts and physical activity also show neuroprotective effects (59, 60).

Our findings are congruent with previous accounts of the beneficial effects of urban green areas on mental health and well-being. Cross-sectional evidence from across Europe has linked residential green space to indicators of better mental health (18, 61-63). In addition, several longitudinal studies have found protective effects (14). To name a few, Alcock et al. (64) conducted a natural experiment and observed an improvement in mental health of participants who moved to a greener residential area. Pun et al. (65) found an inverse relationship between green space and perceived stress, which was partly mediated by increased physical activity. In another cohort study, greater percentage of green space in the residential area related to better mental health, especially in young men (66).

Literature on blue space is thinner, but it also suggests that residential proximity to blue space (67-70) and greater amount of blue space in the neighbourhood (71, 72) may improve mental health.

In the current study, it was interesting that green space was associated with better mental health only in the longitudinal (follow-up) analysis; the same trend was observed in the cross-sectional analysis of the baseline data, but it never reached formal statistical significance, probably because in the summer students spent much less time in Plovdiv (especially those who come from other places) and had not had enough time at baseline (October) to interact with their residential green space for its effect to become significant. Another plausible explanation has to do with seasonal variations in the vegetation levels and mean temperatures in Plovdiv; in May (follow-up), the weather was warmer and the city was "greener" in general than in October (baseline).

Table 1 *Participant characteristics*

Characteristic	(N=109)
Male (N, %)	60 (55.0)
Age (median, IQR)	21.00 (3.00)
Bulgarian (N, %)	48 (44.0)
Economic status (mean, SD)	2.81 (1.26)
Duration of residence ≥5 years (N, %)	19 (17.4)
Time spent at home/day ≥8 hours (N, %)	83 (76.1)

IQR – interquartile range; SD – standard deviation

Table 2 *Correlations between the main, mediator, and outcome variables (N=109)*

Variables	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	Mean	SD
1. NDVI $_{300\text{-m}}$	1.0	-.09	**-.21***	**-.27***	-.14	**-.26***	**-.20***	.06	**.31***	.05	**.36***	.13	.05	**-.31***	.35	.06
2. BS $_{300\text{-m}}$		1.0	.15	.02	-.18	**-.22***	-.07	-.08	**.36***	.13	.15	.07	.09	.13	n/a	n/a
3. L_{Aeq}			1.0	**.60***	.13	.17	.15	.04	.06	.08	-.02	-.19	.08	.19	67.45	1.87
4. NO_2				1.0	.08	.12	.02	.02	.01	.02	.07	-.09	.00	.16	15.62	2.90
5. GHQ_t1					1.0	**.90***	**.59***	**.34***	**-.27***	**-.27***	**-.37***	**-.21***	**-.28***	.09	13.49	7.07
6. GHQ_t2						1.0	**.61***	**.35***	**-.21***	-.18	**-.42***	**-.23***	**-.21***	.10	13.31	6.76
7. EA_t1							1.0	**.44***	**-.27***	-.02	**-.30***	.02	**-.30***	.02	1.70	1.05
8. EA_t2								1.0	-.03	-.05	.03	.04	.05	-.16	1.82	0.93
9. RQ_t1									1.0	**.28***	**.36***	**-.19***	**.41***	.05	4.38	2.46
10. RQ_t2										1.0	-.00	.07	**.40***	**.55***	4.41	2.27
11. PA_t1											1.0	**.24***	.09	-.18	4.62	2.76
12. PA_t2												1.0	-.10	**-.21***	6.08	2.22
13. SC_t1													1.0	**.36***	2.99	1.12
14. SC_t2														1.0	3.03	1.13

BS – blue space; EA – environmental annoyance; GHQ – 12-item General Health Questionnaire; L_{Aeq} – average daily noise level; NDVI – normalised difference vegetation index; NO_2 – nitrogen dioxide; PA – physical activity; RQ – restorative quality; SC – social cohesion; SD – standard deviation; t1 – baseline data (October 2017); t2 – follow-up data (May 2018); $^{*}P<0.05$ (2-tailed)

As for blue space, the association was also stronger in the longitudinal (follow-up) analysis, but in both analyses it was significant, perhaps because water bodies in Plovdiv underwent less change between the baseline and follow-up.

A recent cross-sectional study in Plovdiv illustrated how green/blue space may relate to better mental health through several serial mediation components, including higher perceived green space, restorative quality, physical activity, and lower noise exposure and environmental annoyance (17). Here, we only tested for the effects of a single mediation owing to the relatively small sample size and the lack of statistical power for more sophisticated models. The analysis shows that the restorative quality and physical activity functioned as mediators only in the cross-sectional analysis. There may be several reasons for that. First, it is well known that cross-sectional mediation analysis can yield overconfident results (28). Second, changes in mental health over time could have resulted in a change in mediator variables, not the other way around, which is known as reverse causality. However, it is more likely that these associations were reciprocal and that mental health and mediators influenced each other. Empirical evidence supports this hypothesis. For instance, cohort studies have indicated bidirectional associations between mental health and physical activity (73) and mental health and noise annoyance (74). If such reciprocal effects exist and occur simultaneously (e.g., mental health and physical activity changing together over time), then longitudinal mediation modelling may fail to capture an indirect effect because of inadequate choice of time lag between the two waves of data collection (75, 76). In our longitudinal (follow-up) analysis we assumed that it took about seven months for each mediator variable to result in a change in mental health. However, the choice of this follow-up period was arbitrary and may not have been relevant for physical activity, which may require much shorter time to affect mental health. Other mediator variables may take much longer time. The choice of an optimal follow-up time is a well-known issue in mediation analysis and can seriously affect interpretation (77). In fact, mediation modelling with psychological variables, such as those employed here, may require a shorter follow-up time to reveal the maximum indirect effect, since that effect may fade as a function of time between measurements (77). Several solutions have been proposed to identify the optimal follow-up time, including pilot studies conducted over short time or multi-wave surveys with waves separated by short intervals (77). Hence, future green/blue space research should consider alternative follow-up times and account for them when interpreting cross-lagged regression coefficients.

Strengths and limitations

Our study is one of the few longitudinal studies investigating indirect associations between green/blue space and mental health and it fills the gap in evidence about young people in the southeast of Europe. In addition to methodological contributions, our findings have local importance for public health protection in Bulgaria. CMD prevalence among the youth is relatively high (7, 8), and mental health care in the country is underfunded (6). Therefore, alternative preventive strategies should be explored.

The study has its limitations too. On the design level, our sample is smallish, which could explain some of the null findings. For example, NDVI showed a beneficial trend in the cross-sectional analysis, but the total effect coefficients were not significant. Moreover, we focused on a very specific and narrow group (medical students) in

Table 3 *Single mediation models linking green/blue space to poor mental health (GHQ-12)*

N=109	β (95 % Confidence interval)	
	Cross-sectional (baseline) data	**Longitudinal (follow-up) data**
Total effect of NDVI $_{100\text{-m}}$	1.92 (-14.40, 18.23)	**-8.85 (-16.05, -1.65)***
Indirect effects through:		
L_{Aeq}	-0.08 (-3.01, 1.31)	-0.13 (-1.80, 0.55)
NO_2	-0.06 (-1.54, 0.54)	-0.10 (-0.85, 0.53)
Annoyance	-5.58 (-13.79, 0.45)	0.64 (-0.30, 2.47)
Restorative quality	**-7.38 (-17.55, -1.91)***	1.07 (-0.10, 4.63)
Physical activity	**-4.93 (-14.48, -0.33)***	0.13 (-0.54, 1.99)
Social cohesion	-5.94 (-15.77, 0.27)	0.10 (-0.77, 1.73)
Total effect of NDVI $_{300\text{-m}}$	-12.88 (-37.98, 12.21)	**-16.08 (-24.05, -8.10)***
Indirect effects through:		
L_{Aeq}	-0.10 (-5.08, 4.67)	-0.62 (-4.11, 0.40)
NO_2	-0.26 (-5.03, 5.48)	-0.63 (-2.25, 1.61)
Annoyance	-9.21 (-23.94, 0.89)	1.15 (-0.29, 4.90)
Restorative quality	**-8.56 (-24.36, -1.58)***	0.13 (-1.68, 2.81)
Physical activity	**-8.61 (-22.97, -1.30)***	0.10 (-0.80, 2.29)
Social cohesion	-5.61 (-16.82, 2.40)	0.54 (-1.89, 3.98)
Total effect of NDVI $_{500\text{-m}}$	-17.73 (-52.03, 16.57)	**-16.00 (-25.87, -6.13)***
Indirect effects through:		
L_{Aeq}	1.08 (-7.61, 12.72)	-0.25 (-5.54, 3.67)
NO_2	1.58 (-8.52, 19.29)	-0.50 (-3.89, 5.24)
Annoyance	-7.10 (-26.73, 7.01)	0.12 (-1.34, 2.96)
Restorative quality	**-10.00 (-31.57, -1.13)***	1.05 (-0.54, 5.81)
Physical activity	-2.19 (-15.23, 4.93)	0.52 (-1.22, 4.46)
Social cohesion	-5.96 (-19.47, 3.29)	0.44 (-2.48, 4.51)
Total effect of BS $_{300\text{-m}}$	**-4.78 (-9.47, -0.08)***	**-2.21 (-3.95, -0.47)***
Indirect effects through:		
L_{Aeq}	0.10 (-0.35, 1.10)	0.09 (-0.05, 0.53)
NO_2	-0.0002 (-0.17, 0.20)	0.0001 (-0.08, 0.08)
Annoyance	-0.92 (-3.96, 1.70)	-0.07 (-0.52, 0.20)
Restorative quality	**-1.87 (-4.27, -0.33)***	-0.01 (-0.75, 0.47)
Physical activity	**-1.06 (-2.81, -0.15)***	0.02 (-0.10, 0.33)
Social cohesion	-0.82 (-2.37, 0.45)	-0.06 (-0.55, 0.19)
Total effect of BS $_{500\text{-m}}$	-1.06 (-5.40, 3.29)	-0.81 (-2.17, 0.55)
Indirect effects through:		
L_{Aeq}	-0.02 (-0.63, 0.23)	0.004 (-0.13, 0.23)
NO_2	-0.01 (-0.70, 0.27)	0.002 (-0.14, 0.14)
Annoyance	0.99 (-1.10, 3.32)	-0.16 (-0.66, 0.05)
Restorative quality	**-1.40 (-3.52, -0.21)***	0.13 (-0.12, 0.78)
Physical activity	-0.28 (-1.65, 0.58)	0.06 (-0.15, 0.48)
Social cohesion	-0.03 (-1.48, 1.37)	-0.06 (-0.66, 0.29)

*BS – blue space; GHQ-12 – 12-item General Health Questionnaire; L_{Aeq} – average daily noise level, NDVI – normalised difference vegetation index; NO_2 – nitrogen dioxide. There is no model for BS in the 100-m buffer, because participants did not live so close to blue space. All models were adjusted for age, sex, ethnicity, individual-level economic status, duration of residence, time spent at home/day. NDVI and BS are mutually adjusted. All variables included in the cross-sectional data models are measured at baseline (October 2017). The longitudinal data models include GHQ and self-reported mediator values measured at follow-up (May 2018) and are adjusted for their values at baseline (October 2017). Effect size coefficient is unstandardized regression coefficient (95 % CI). *Coefficient is statistically significant at $p<0.05$.*

which foreign students are overrepresented; all of that limits interpretation and general application but does not necessarily diminish the internal validity of our results. Furthermore, we limited our investigation to green/blue space around student residences, ignoring the possible effects of other green/blue space to which the students may be exposed along their commuting routes.

Mediator variables restorative quality and social cohesion were measured using a reduced number of items from the original questionnaires. This could have attenuated the associations with other variables in the model.

Finally, the choice of the follow-up time was arbitrary and guided by convenience, about which we have discussed in the previous section.

Limitations notwithstanding, we suspect that the associations we found are more likely to have been underestimated than overestimated.

CONCLUSION

The effects of green space and blue space on mental health differed depending on whether the associations were modelled with cross-sectional (baseline) or longitudinal (follow-up) data. In the first case, higher residential green space was associated with better mental health only indirectly through higher physical activity and restorative quality. The follow-up data confirmed that higher green space improves mental health, but the effects of mediator variables were not significant. Similarly, blue space was beneficial for mental health, but mediation by physical activity and restorative quality was observed only in the cross-sectional analysis. Our findings support earlier reports of green and blue space as psychologically beneficial for mental health. Future research should replicate these findings in the general population and employ longitudinal modelling tailored to the specific mechanisms under study.

Acknowledgements

I am grateful to the participating students for making this study possible. I would also like to thank Dr Iana Markevych for her assistance with the geographic analyses.

Conflict of interests

None to declare.

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Preliminarno praćenje povezanosti stambenih zelenih i vodenih površina s boljim mentalnim zdravljem u sveučilišnih studenata

Rezultati presječnih istraživanja upućuju na to da prirodni okoliš u gradovima (zelene i vodene površine) povoljno utječe na mentalno zdravlje, ali tek je nekoliko dugoročnih istraživanja pokušalo utvrditi mehanizme u pozadini tog učinka. Cilj ovoga preliminarnog (pilot) istraživanja bio je ispitati mehanizme/varijable koji posreduju između zelenih/vodenih površina u mjestu stanovanja i tjeskobe/depresije u 109 bugarskih studenata sa Sveučilišta u Plovdivu. Studenti su praćeni od početka do kraja akademske godine (od listopada 2017. do svibnja 2018.). Stambeno se zelenilo odredilo pomoću normaliziranog indeksa razlike u vegetaciji (engl. *normalised difference vegetation index*, krat. *NDVI*) u radijusu od 100, 300 i 500 m oko adrese stanovanja. Udio vodenih površina također je procijenjen u tim radijusima. Razine tjeskobe/depresije ocijenjene su pomoću 12 stavki iz Upitnika o općem zdravstvenom stanju (*General Health Questionnaire*, krat. *GHQ-12*). Od posredničkih (engl. *mediator*) varijabli istražili smo buku, onečišćenje zraka (NO_2), uzrujanost okolišem, percepciju utjecaja susjedstva na oporavak (engl. *restorative quality*), društvenu povezanost u susjedstvu (engl. *social cohesion*), tjelesnu aktivnost i poremećaj spavanja. Podaci iz presječnoga istraživanja (dobiveni za početnog mjerenja) pokazali su da viši *NDVI* korelira s boljim mentalnim zdravljem tek neizravno kroz izrazitiju tjelesnu aktivnost i snažniji utjecaj na oporavak u susjedstvu. Dugoročno je pak istraživanje (praćenje) pokazalo istu tu korelaciju, ali bez značajnog sudjelovanja posredničkih varijabli. Slično je i s vodenim površinama. Njihov veći udio korelirao je s boljim mentalnim zdravljem u svim modelima, ali su tjelesna aktivnost i oporavak značajno posredovali samo u presječnom istraživanju (početnom mjerenju). Naši rezultati potvrđuju povoljan psihološki utjecaj gradskih zelenih i vodenih površina na psihu i njezin oporavak, ali će tek buduća istraživanja trebati to potvrditi i u općoj populaciji. U dugoročnim bi istraživanjima svakako trebalo prilagoditi modeliranje konkretnim mehanizmima koji se ispituju.

KLJUČNE RIJEČI: *depresija; modeliranje posredničkih varijabli; tjeskoba; voda; zelenilo*