The role of natural environments in the effectiveness of brief mindfulness-based stress reduction (brief MBSR): depression, anxiety, stress and hair cortisol from a randomized trial

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Background: To date, there is a considerable amount of evidence on the positive effects of exposure to natural environments on mental health and wellbeing. This field of research does not sit within medical or health care disciplines and it has been slow to penetrate them. Thus, this study aims to explore the potential for enhancing the effectiveness of an intervention by combining it with exposure to a natural environment on stress-related symptoms.

Methods: Participants (n=99) were randomly assigned to a weekly one-hour brief mindfulness-based stress reduction (MBSR) in one of three different environments (i.e., natural outdoor, built outdoor and indoor setting) over a six-week period. They were asked to complete the questions in depression anxiety stress scales (DASS-21) four times during the research period at before MBSR (T0), during MBSR (T1), after MBSR (T2) and one-month follow-up (T3). The participants who completed at least five MBSR sessions were invited to donate hair samples to measure the physiological changes of stress levels.

Results: The results of DASS-21 showed that all three groups experienced changes in levels of depression, anxiety and stress during the intervention. In particular, participants' depression and stress levels were more decreased in the natural outdoor environment, compared to other environments. However, no significant differences in hair cortisol concentration (HCC) between the environments were found.

Conclusions: This study offers valuable insights into the role of natural environments in the effectiveness of a therapeutic intervention. The findings have applications relevant to clinical settings for the treatment of mental health issues, or where the alleviation of stress, anxiety or pain is a priority.

Trial Registration: This study was registered at ClinicalTrials.gov (ID: NCT05451758).

Keywords: Mental health; wellbeing; depression; anxiety; hair cortisol

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Introduction

Extensive research has shown positive effects of exposure to natural environments on mental health and wellbeing. These studies suggest that spending time in natural environments can reduce stress (1,2), improve emotional restoration (3), enhance self-esteem and life satisfaction (4), and increase attention and memory (5). The psychological influence of exposure to natural environments has been widely recognised in the context of the Attention Restoration Theory (ART) (6) and Stress Reduction Theory

(SRT) (7). Both ART and SRT focus on the benefits of restoration opportunities in natural environments. However, ART emphasises the restoration of a functional capability, while SRT highlights the reduction of psycho-physiological stress. ART incorporates concepts of directed attention, involuntary attention, and cognitive restoration from mental fatigue. Directed attention involves mental effort to perform cognitive assignments, such as report writing or answering questions. The absence of directed attention when brain capacity is exhausted results in mental fatigue and tiredness. Unlike directed attention, involuntary attention (or fascination) is less mentally strenuous and serves to replenish the function of directed attention (8). According to ART, specific settings promote involuntary attention and offer a "restorative environment" in terms of (I) being away; (II) involuntary "soft fascination" without cognitive effort; (III) a sense of "extent" (i.e., physically or conceptually large enough that one's mind can wonder within it); and (IV) harmonious relationship between one's predispositions and the attributes of the surroundings (8,9). These four characteristics of the restorative environment allow people to have positive and favourable experience with less disturbance; this enables them to recuperate and restore their directed attention. Previous studies highlighted the significance of the natural environmental settings, compared to other settings, in offering restorative opportunities (10,11).

In contrast, according to SRT, changes in emotional state lead to a lowering of stress through the restorative influences of natural environments. An experimental study compared the recovery from surgery of two groups of patients when they were exposed to the views of natural environment and built environment (i.e., a brick wall) (7). This experiment revealed that the patients who had the view of natural environment required less medication, experienced lower post-surgical problems, and were discharged earlier from the hospital compared with those who had the built environment. Similarly, the exposure to natural environments (i.e., natural sights and sounds) effectively distracted patients from their stress and pain (12). As people distinctively perceive the natural environment as non-aggressive (13), it allows them to feel more positive emotion and reduces their physiological activation. Therefore, natural environments prompt faster recuperation from severe stress, prevent the occurrence of chronic stress, and ensure one's adaptability to stressful conditions (7). Several studies have supported SRT by linking exposure to the natural environment and restorative psycho-physiological responses, such as reduced heart rate (14), blood pressure (15) and cortisol levels (2). The concepts of both ART and SRT have been substantiated in previous studies that have compared restorative benefits in the natural settings and urban settings (5,16), and natural settings and indoor settings (17,18). Recent studies also explored differential restoration values of different natural environmental settings (19,20) and different ways of being exposed to natural environments (21,22).

As the restorative effects of natural environments are acknowledged, health and social care practitioners are turning to interventions that incorporate natural settings to improve psychological and physiological health (23). For example, professional therapists who are skilled in horticulture administered the Social and Therapeutic Horticulture (STH), which incorporated general gardening activities in a structured and formalised programme, for vulnerable groups who experience mental health problems (24). Forest bathing (*Shinrin-yoku*) is also used to promote relaxation and help recovery of emotional balance. A scoping review showed the impact of nature-based interventions on cortisol (25); however, those studies did not include a long-term follow-up and did not analyse hair samples. Thus, more rigorous longitudinal research is needed to assess the utility of nature-based interventions as a health promotion intervention to reduce stress. Particularly, there are several attempts to examine the effects of mindfulness programme when combined with natural environments. The participants' concentration and mood before and after a mindfulness training at an indoor campus setting or an outdoor garden setting (26). A study also examined a change in positive emotions during 15-min mindfulness practice in a natural (i.e., a local arboretum) or a built environment (i.e., an outdoor stadium) (27). In addition, the experience of mindful awareness can be utilised to enhance a feeling of nature connection and the restorative qualities of natural environments (28). This suggests that the practice of mindfulness can be a tool to enhance and assist progress towards the goal of fostering a human-nature connection, leading to positive mental health and wellbeing.

Mindfulness practice has heightened as one such complementary and alternative approach to coping with poor mental health conditions such as stress, anxiety and depression. Practicing mindfulness leads to non-judgemental and non-reactive acceptance of all experience, which results in psychological resilience improvement (29). This has developed standardised mindfulness-based interventions (MBIs), which integrate the essence of traditional mindfulness meditations with contemporary psychological practice to improve health and wellbeing (30). The most widely used MBI is mindfulness-based stress reduction (MBSR), which incorporates various mindfulness practices that seek to manage the pain and stress recovery processes (31). The duration of standard MBSR format is eight weeks, during which up to 30 participants are grouped to meet for two hours on a weekly basis to participate in mindfulness practices (e.g., sitting and body-scanning meditation, and mindfulness movement). The effectiveness of MBSR as a wellbeing intervention has been explored in various prior studies within both clinical and non-clinical contexts. The findings on the psychological effects of MBSR revealed positive results, including stress reduction (32) and preventing emotional distress, depression and anxiety (33). More recently, a brief MBSR format has been introduced to help full-time workers and students to manage time and schedule requirements (34). A four-week MBSR, which involved a 30-minute group session per week and a 10-minute home practice per week, significantly reduced stress and mental fatigue, and improved the participants' life satisfaction despite its brief implementation (35). Similarly, brief MBSR involving a five-minute group session on a daily basis for four weeks substantially reduced the participants' stress levels from the baseline (36). It is now well established the effectiveness of standard MBSR or brief MBSR on health and wellbeing. So far, however, evaluating health-related interventions has focused on the efficacy of the intervention alone and overlooked the impact of an environments where they are carried out.

This study attempts to provide a fine-grained insight into existing knowledge of the enhancement of natural environments via the experimental design and the multiple outcome measures. We investigated the potential for enhancing the effectiveness of brief MBSR by combining it with exposure to a natural environment on stress-related symptoms. Specifically, it assessed whether a natural environment enhance the beneficial effects of brief MBSR on stress, anxiety and depression, and hair cortisol concentration (HCC). We present the following article in accordance with the CONSORT reporting checklist (available at https://jphe.amegroups.com/article/view/10.21037/jphe-22-13/rc).

Methods

Participants

Participants were recruited from students and staff at the University of Sheffield though the university volunteer email. The participants were required to complete a screening questionnaire to register their interest in the project. The participants were eligible to participate in the intervention if they were 18 years of age or older, and had no severe and enduring mental health conditions (i.e., currently receiving treatment for such conditions). For power =0.95 and α=0.05, 69 participants were calculated to be sufficient to detect a small-medium effect (f=0.20). Initially, 113 students and staff agreed to participate in this study. A sample of 99 participants was randomly selected by stratified random sampling to ensure a proportional number of male (37 male, 37.3%) and female (62 female, 62.7%) university students and staff. We randomly allocated the participants to different groups (participant characteristics by environment can be found in Table S1). All participants had the opportunity to be entered into a prize draw to win 10× prizes of 50 British pound sterling (GBP). *Figure 1* shows the CONSORT diagram illustrating the flow of participants from enrolment to analysis.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The ethical approval for this study was obtained from the University of Sheffield's Research Ethics Committee (reference number 015171).

Design and procedure

Potential participants were emailed a link to a consent form, a participant information sheet and a baseline questionnaire which they were asked to complete before attending the experiment. Once participants completed them, they were randomly assigned to brief MBSR in one of the three different environments. A week before starting the experiment, participants were contacted via email with instructions about the start of the study. However, participants were not aware of the environmental conditions in which they were placed, to reduce potential bias by preventing the foreknowledge of the intervention. The participants were asked to attend the brief MBSR

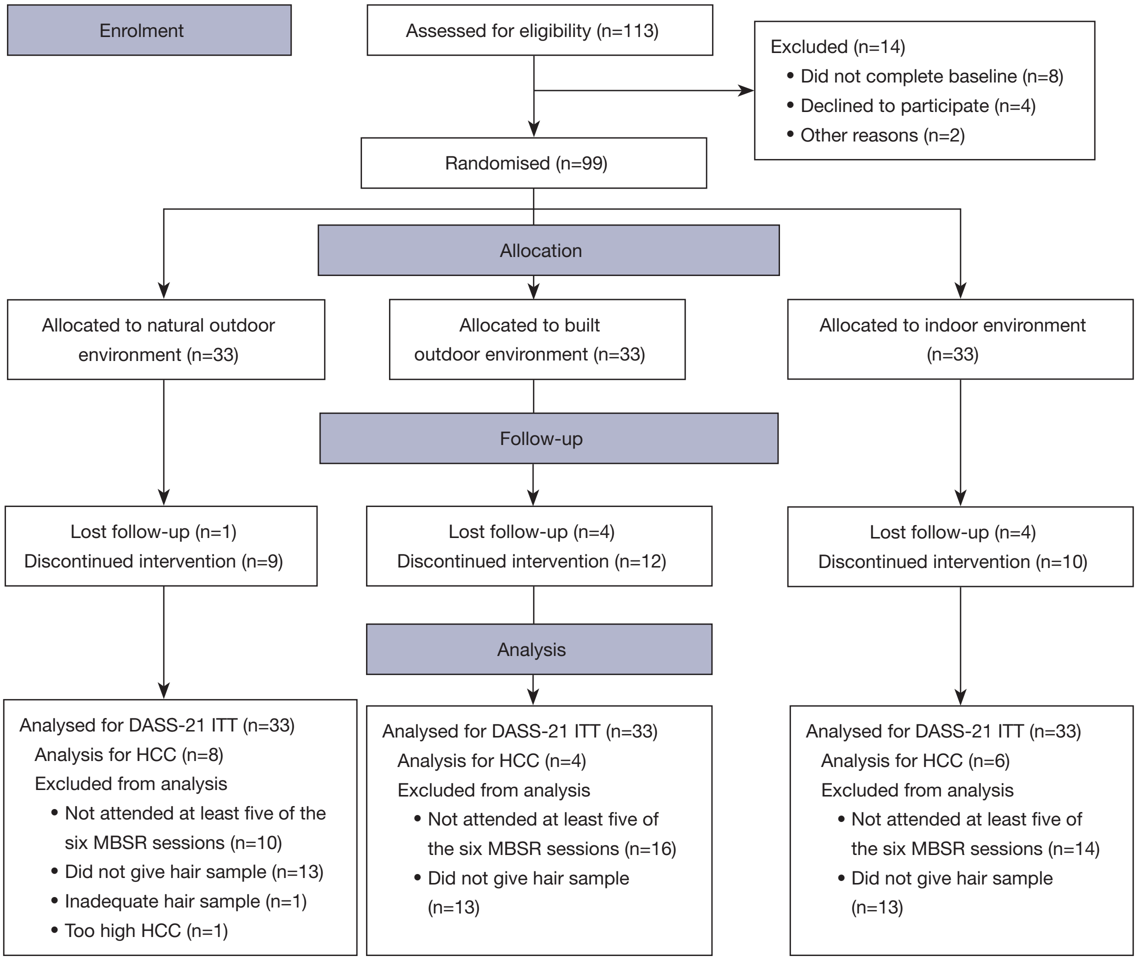

Figure 1 CONSORT flow diagram. DASS-21, depression anxiety stress scales; ITT, intention-to-treat; HCC, hair cortisol concentration; MBSR, mindfulness-based stress reduction.

programme for 6 weeks with 1-hour sessions. The weekly MBSR session included sitting and body scanning meditation, mindfulness exercises and group discussion led by a qualified mindfulness facilitator. During the experiment, participants were asked to complete the same questions in DASS-21 four times, before MBSR (T0), during MBSR (T1), after MBSR (T2) and one-month follow-up (T3).

In addition, participants who attended at least five of the six MBSR sessions were invited to donate their hair samples to measure the change of their stress level. In the second half of the experiment, the participants were given information about measuring hair cortisol. Once participants agreed to donate their hair samples (5 mm diameter max), the researcher arranged a date and time for hair collection one month after the completion of the MBSR programme. Collecting of hair samples took about five minutes. On the basis of guidelines from prior studies (37), samples were excluded if participants reported using dye or bleach on their hair in the past year or were currently using pharmaceutical glucocorticoids. Once the hair sample was collected, it was packed and sent immediately to the biomarker analysis laboratory at Anglia Ruskin University.

Environmental variables

Participants were exposed to one of the three different environments located in Sheffield, UK. These three research areas were chosen for this study within a radius

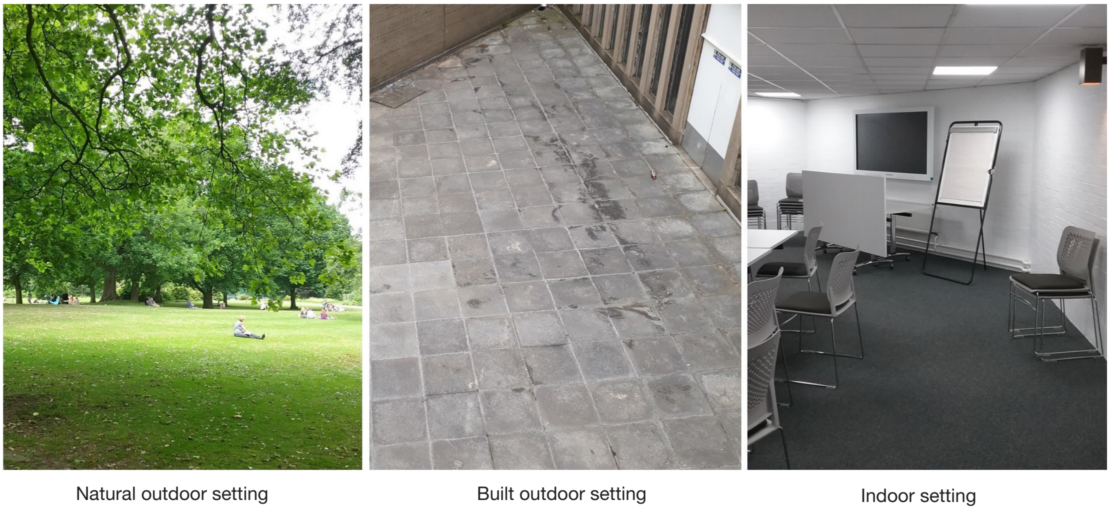

Figure 2 Three different experimental settings.

of 200 m of the main campus: (I) a park, representing a natural outdoor setting; (II) a shelter, representing a built outdoor setting; and (III) a seminar room in the basement, representing an indoor setting. A park setting is a public park with an area of over 5 hectares near the university. The park is a well-managed green area with trees, shrubs, flower beds, lawns and lake including facilities such as benches, wooden bridges, bandstand and monuments. As shown in *Figure 2*, it is well-tended and open, so that distant elements within the park can be seen. The participants' view during the experiment in the park was towards a sparsely vegetated area with mature trees and shrubs, set in mown grass. There was background noise during the experiment, such as people talking and laughing in the distance, and birds singing. A shelter was chosen as a built outdoor setting. The shelter is surrounded by grey walls making it isolated. The key feature of this setting is that it contained no vegetation. There was background noise, such as passing cars and sound of traffic lights. The final control environment, a seminar room was a white painted room without windows in the basement of a university building.

Measures

To examine the changes in participants' phycological stress-related reactions, we asked participants to complete a questionnaire four times during the research period at before MBSR (T0), during MBSR (T1), after MBSR (T2) and one-month follow-up (T3). The questionnaire contains questions on DASS-21 and demographic details, such as age and gender. In addition, participants who completed at least five MBSR sessions (n=59) were invited to donate their hair samples to measure the physiological changes of stress levels.

Depression anxiety stress scales (DASS-21)

The DASS-21 contains psychological measures related to the negative emotional states associated with depression, anxiety and stress in the form of 21 questions (38,39). DASS-21 is a set of three self-report subscales designed to assess the negative emotional states of depression, anxiety and stress on a four-point scale (0= never, 3= almost always); each of the three subscales contains seven items. The depression scale assesses feelings of unhappiness, hopelessness, and lack of interest. The anxiety scale measures subjective experiences of insecurity and uncertainty. The stress scale measures difficulty relaxing, being easily upset, irritable and over reactive. The range of scores for each subscale is from 0 to 21, with higher scores reflecting more depression, anxiety and stress. Cronbach's α was 0.89 for depression, 0.82 for anxiety and 0.83 for stress.

HCC

HCC is used as a marker of chronic stress. Cortisol is commonly known as the stress hormone because it is released via the hypothalamic-pituitary-adrenal (HPA) in higher doses under stressful conditions (40,41). The extraction of cortisol from hair has been developed as a new method to measure cortisol exposure in humans. Assuming hair grows approximately 1 cm per month, hair analysis provides the possibility to show the average long-term activity of cortisol exposure, and to compare several hair segments/months with each other, including segments before the presence of a stressful event (42). For example, HCC from a 3 cm of hair sample can reflect the past 3 months of cortisol secretion.

Analysis strategy

DASS-21

An intention-to-treat (ITT) analysis was used for DASS-21 outcomes in which all participants were included (n=99) in the statistical analysis and analysed according to the group they were originally assigned. ITT analysis is widely used to avoid over-optimistic results of the effectiveness of an intervention resulting from the removal of non-compliers by including protocol deviations and withdrawal, all of which are likely to occur in actual clinical practice (43). Firstly, Chi-squared and analysis of variance (ANOVA) were used to examine differences at baseline. Next, multivariate analysis of variance (MANOVA) was used to examine interaction effects using three environments (natural outdoor, built outdoor and indoor setting) × four times [before MBSR (T0), during MBSR (T1), after MBSR (T2) and one-month follow-up (T3)]. If there was a significant environment by time interaction, follow-up analysis was performed using *t*-tests. All analysis was carried out using SPSS 24.0 using an alpha of 0.05. We also report effect size, indicating small (η^2=0.01), medium (η^2=0.06), and large (η^2=0.14) effects (44).

HCC

Hair samples were available and usable from 18 participants: 8 (natural outdoor setting), 4 (built outdoor setting) and 6 (indoor setting). These were analysed by following standard procedure at the biomarker analysis laboratory at Anglia Ruskin University, UK. The cortisol result was adjusted for the individual hair weight of the sample and the result of HCC was reported in pg/mg. HCC from a 4 cm hair sample reflects the past 4 months of cortisol secretion; the 1 cm segment most proximal to the scalp was assayed to indicate the one-month follow-up cortisol output. The second most proximal 1 cm segment represented the month after the experiment. The third most proximal 1 cm segment was assayed to indicate cortisol output for the month during the intervention, and the fourth most proximal 1 cm segment was assayed to indicate cortisol output for the month before the intervention. Statistical analysis of HCC was carried out using SPSS 24.0 using an alpha of 0.05. MANOVA was used to determine whether there is a significant environmental effect on changes in HCC.

Results

Self-reported depression, anxiety and stress symptoms

Given that the effects of MBSR have been shown to differ according to age and gender, baseline data were examined (45). A total of 99 participants was eligible for analysis (37 male and 62 female; mean age 36.35; range, 16–62 years). No significant differences based on age (χ^2=80.20, P=0.19) and gender (χ^2=0.09, P=0.96) were found between the experimental conditions. Univariate ANOVAs revealed no baseline differences in any of the study measures by environment, P>0.05.

Next, MANOVA was used to examine the main effect of time and environments on all measures; it revealed the main effect of time was significant, F(9,696)=6.23, P<0.001, η^2=0.06. There were also statistically significant interactions between the three environments (natural outdoor, built outdoor and indoor) and four time points (T0, T1, T2 and T3), F(18,809)=2.07, P=0.005, η^2=0.04, at the multivariate level. *Table 1* shows the means, standard deviations and confidence intervals for all measurements by environment at the three time-points.

Depression

A repeated measures ANOVA revealed that time had a significant effect on depression, F(3,94)=7.60, P<0.001, η^2=0.20. There was also a significant environment by time interaction, F(6,188)=2.17, P=0.04, η^2=0.07. The results indicate that participants' depression levels differed significantly across four time points and there was a significant impact of environment on depression.

Paired samples *t*-tests were used to investigate further the impact of brief MBSR in each environmental group. In the natural outdoor setting, there was a statistically significant decrease in depression from T0 (M =10.73, SD =8.24) to T3 (M =6.55, SD =6.86); t(32)=3.17, P=0.003, η^2=0.55. However, *t*-tests revealed no significant difference in the built outdoor setting from T0 (M =10.24, SD =7.51) to T3 (M =8.06, SD =6.71); t(32)=1.94, P=0.06, η^2=0.04, and in the indoor environment from T0 (M =9.45, SD =8.10) to T3 (M =6.73, SD =7.98); t(32)=2.91, P=0.07, η^2=0.34. Therefore, depression levels were significantly decreased in only the MBSR group in the natural outdoor, not in other

Table 1 Mean, standard deviation (SD) and 95% confidence interval (CI) for DASS-21 at three time points

Outcome	Before MBSR (T0): M (SD)/95% CI	During MBSR (T1): M (SD)/95% CI	After MBSR (T2): M (SD)/95% CI	Follow-up (T3): M (SD)/95% CI
DASS-21: depression				
Natural outdoor	10.73 (8.24)	7.94 (7.48)	6.55 (6.33)	6.55 (6.86)
	7.80–13.65	5.29–10.59	4.30–8.79	4.11–8.98
Built outdoor	10.24 (7.51)	9.27 (7.19)	10.36 (5.04)	8.06 (6.71)
	7.58–12.91	6.72–11.92	8.58–12.15	5.68–10.44
Indoor	9.45 (8.10)	7.15 (6.33)	7.24 (6.57)	6.73 (7.98)
	6.58–12.33	4.91–9.39	4.91–9.57	3.90–9.56
Total	10.14 (7.83)	8.12 (6.99)	8.05 (6.19)	7.11 (7.17)
	8.57–11.72	6.73–9.52	6.82–9.28	5.68–8.54
DASS-21: anxiety				
Natural outdoor	9.39 (7.37)	8.06 (6.59)	6.73 (6.69)	5.94 (7.06)
	6.78–12.01	5.73–10.40	4.36–9.10	3.44–8.44
Built outdoor	7.88 (6.18)	7.70 (4.10)	7.79 (3.10)	6.79 (5.98)
	5.69–10.07	6.24–9.15	6.69–8.89	4.67–8.91
Indoor	9.24 (9.09)	6.91 (7.02)	6.30 (5.86)	6.12 (6.32)
	6.02–12.47	4.42–9.40	4.23–8.38	3.88–8.36
Total	8.84 (7.60)	7.56 (5.99)	6.94 (5.42)	6.28 (6.41)
	7.32–10.35	6.36–8.75	5.86–8.02	5.00–7.56
DASS-21: stress				
Natural outdoor	16.61 (8.05)	11.94 (5.91)	10.48 (6.98)	9.82 (6.21)
	13.75–19.46	9.85–14.03	8.01–12.96	7.62–12.02
Built outdoor	16.79 (8.47)	15.09 (6.93)	14.21 (8.35)	14.70 (8.93)
	13.78–19.79	12.63–17.55	11.25–17.17	11.53–17.86
Indoor	15.12 (10.02)	12.79 (7.31)	13.82 (6.15)	12.85 (6.37)
	11.57–18.67	10.19–15.38	11.64–16.00	10.59–15.11
Total	16.17 (8.83)	13.27 (6.81)	12.84 (7.34)	12.45 (7.48)
	14.41–17.93	11.92–14.63	11.37–14.30	10.96–13.95

DASS-21, depression anxiety stress scales; MBSR, mindfulness-based stress reduction.

setting (*Figure 3*).

Anxiety

A repeated measures ANOVA revealed that time had a significant effect on anxiety, $F(3,94)=6.26$, $P=0.001$, $\eta^2=0.17$. There was no significant environment by time interaction, $F(6,188)=1.15$, $P=0.33$, $\eta^2=0.04$. The results show that participants' anxiety levels differed significantly across four time points but there was no significant impact of environment on anxiety (*Figure 4*).

Stress

A repeated measures ANOVA revealed that time had a significant effect on stress, $F(3,94)=9.49$, $P<0.001$, $\eta^2=0.23$. There was also a significant environment by time interaction, $F(6,188)=2.19$, $P=0.04$, $\eta^2=0.07$. This indicates

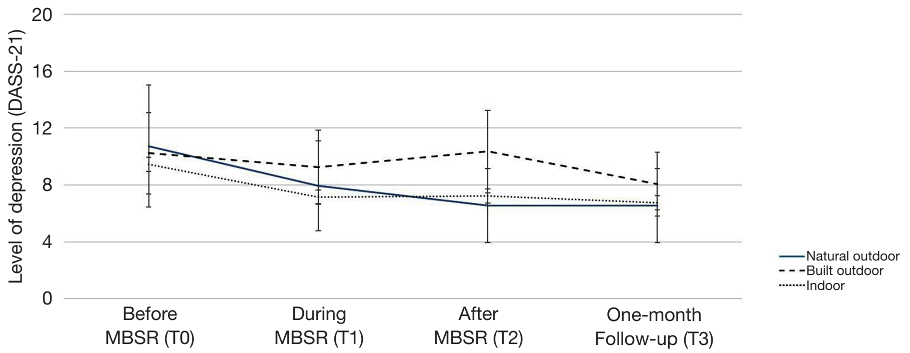

Figure 3 Interaction graph for depression (DASS-21); error bars denote using a 95% confidence interval. DASS-21, depression anxiety stress scales; MBSR, mindfulness-based stress reduction.

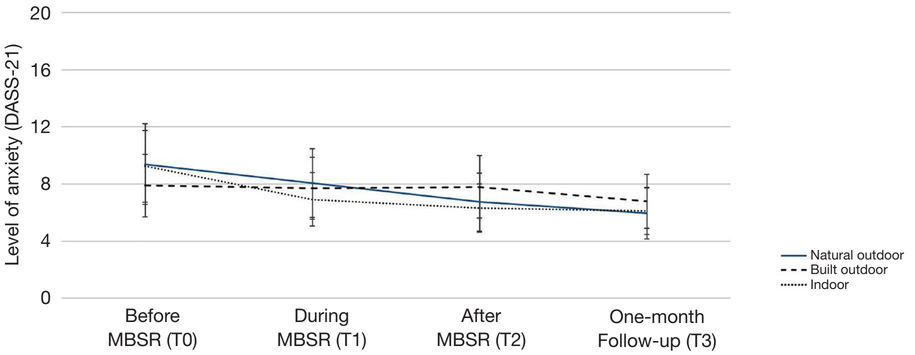

Figure 4 Interaction graph for anxiety (DASS-21); error bars denote using a 95% confidence interval. DASS-21, depression anxiety stress scales; MBSR, mindfulness-based stress reduction.

that participants' stress levels differed significantly across four time points and there was a significant impact of environment on stress.

Paired samples *t*-tests found a significant difference in the natural outdoor setting from T0 (M =16.61, SD =8.05) to T3 (M =9.82, SD =6.21), t(32)=5.42, P<0.001, η^2=0.94. However, there was no significant decrease in the built outdoor setting from T0 (M =16.79, SD =8.47) to T3 (M =14.70, SD =8.93); t(32)=1.72, P=0.10, η^2=0.94, and in the indoor setting from T0 (M =15.12, SD =10.02) to T3 (M =12.85, SD =6.37); t(32)=1.79, P=0.08, η^2=0.27. Therefore, stress levels were significantly decreased in only the MBSR group in the natural outdoor, not in other settings (*Figure 5*).

Physiological stress system activity

Sample characteristics

The initial hair samples consisted of 18 participants. One failure to provide an adequate hair sample and one outlier which HCC was extremely high were excluded. This resulted in 16 samples which were eligible for inclusion in the analysis (4 male and 12 female; mean age 31.38; range, 24–57 years). *Table 2* shows the means and standard deviations for HCC by environment at four time-points.

HCC

As shown in *Figure 6*, time had a significant effect on HCC, F(3,11)=4,93, P=0.02, η^2=0.57; cortisol levels decreased over study duration. However, there was no statistically significant interaction between environment and time but the effect size was large, F(6,22)=1.51, P=0.22, η^2=0.29. The results show the environments did not affect to participants' physiological stress system activity, although the effects observed were larger than for the self-report measures.

Discussion

We examined changes in stress-related psychological

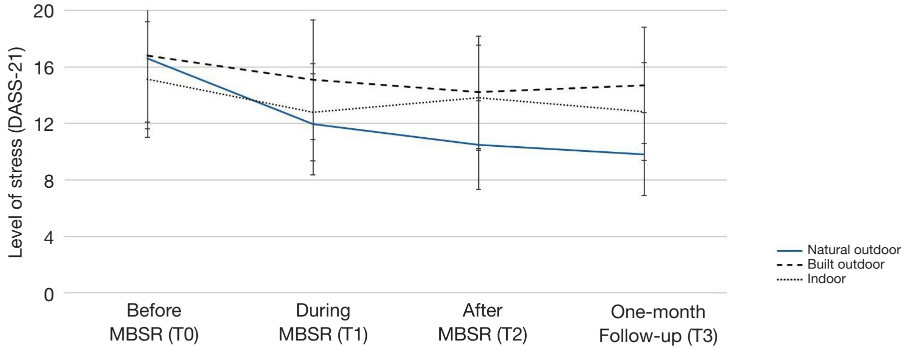

Figure 5 Interaction graph for stress (DASS-21); error bars denote using a 95% confidence interval. DASS-21, depression anxiety stress scales; MBSR, mindfulness-based stress reduction.

Table 2 Mean, standard deviation (SD) and 95% confidence interval (CI) for HCC at four time points

Group	Before MBSR (T0): M (SD)/95% CI	During MBSR (T1): M (SD)/95% CI	After MBSR (T2): M (SD)/95% CI	Follow-up (T3): M (SD)/95% CI
Natural outdoor (n=6)	6.74 (1.52)	6.67 (1.49)	6.20 (1.12)	5.65 (1.27)
	5.14–8.33	5.10–8.23	5.02–7.38	4.31–6.98
Built outdoor (n=4)	6.22 (1.50)	6.22 (1.50)	5.65 (0.66)	5.41 (0.34)
	3.84–8.61	3.84–8.61	4.60–6.70	4.85–5.96
Indoor (n=6)	6.40 (0.42)	6.39 (0.78)	5.91 (1.06)	5.74 (0.89)
	5.95–6.84	5.95–6.84	4.80–7.02	4.81–6.67
Total (n=16)	6.48 (1.15)	6.45 (1.13)	5.95 (0.96)	5.62 (0.92)
	5.87–7.09	5.85–7.05	5.44–6.47	5.13–6.11

HCC, hair cortisol concentration; MBSR, mindfulness-based stress reduction.

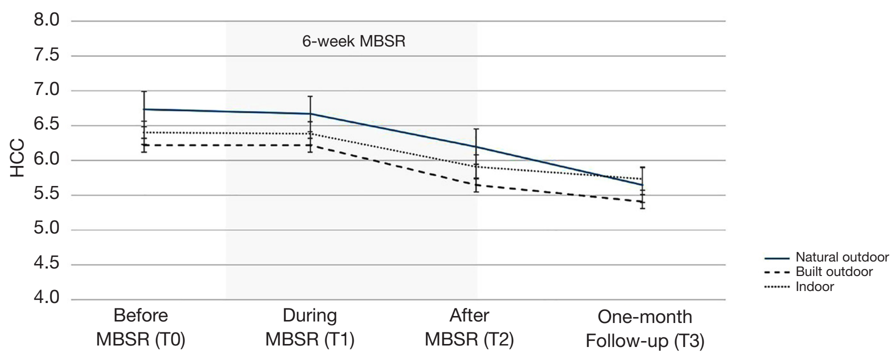

Figure 6 Interaction graph for HCC; error bars denote using a 95% confidence interval. MBSR, mindfulness-based stress reduction; HCC, hair cortisol concentration.

and physiological outcomes following a brief MBSR programme. The results of DASS-21 showed that all three groups (i.e., natural outdoor, built outdoor and indoor setting) experienced changes in levels of depression, anxiety and stress during the intervention. In addition, participants' depression and stress levels were more decreased in the natural outdoor setting, compared to other settings. Particularly, there were significant differences between environments at one-month follow-up. For example, the groups' stress level decreased over the research period, but the participants in the built outdoor and indoor groups did not change between during MBSR and follow-up. This suggests that the effect of brief MBSR last longer when conducted in the natural outdoor settings. This finding is consistent with other research which found that natural environments enhanced the effectiveness of mindfulness interventions. A study found that participants who walked in a natural environment with a guided 20 minutes' mindfulness practice reported greater awareness of their surroundings, stronger nature connectedness and less negative emotions than individuals without it (46). Experiences in nature can support meditative states through soft fascination (involuntary attention without cognitive efforts) and by being away (47). Mindfulness practices, in turn, can help people become positively engaged and curious toward restorative environmental conditions. Thus, people could reduce stress through mindfulness practice in nature by achieving psychological distance from stressors and distraction (48). Further, several studies have demonstrated the physical, social and psychological benefits of these nature-based activities, such as improvements in mood, self-esteem and social interaction, and reductions in stress, anxiety and depression (49,50). However, the precise mechanism of interaction effects remains to be elucidated. The question raised by this study is whether there is different between depression, stress and anxiety. Further work is needed to fully understand such interactions in different mental health concerns.

The result of cortisol analysis differs from the findings of self-reported psychological measures. Although HCC decreased over time in the whole sample, the type of environment was unrelated to the extent of those decreases, which contrasts with the enhanced benefits of brief MBSR on subjective depression and stress in the natural environment. The improvement in perceived stress has been a consistent result in this field, but literature has emerged that offers contradictory findings about physiological stress outcomes. An improvement on self-reported psychological distress, anxiety, depression, and burnout, but no change in hair cortisol after MBSR (51). A previous study also did not find the differences in salivary cortisol and heart rate variability (HRV) between natural and urban settings (52). Similarly, the reduction of blood pressure reactivity to stress after MBSR, but no effects were found with other physiological measures, such as HRV and salivary cortisol (53). This inconsistency may be because the analyses of hair cortisol was based on a smaller sample of participants; our a priori sample size calculation indicated 69 participants were required. Alternatively, we found that a significant correlation between change in self-report stress (DASS-21) and change in cortisol was observed ($r=0.74$, $P=0.01$). Stress remains largely a subjective experience, being influenced by how we perceive stressful situations. Mindfulness practices could lead participants to observe their painful emotions/thoughts without judgment. This may occur as a result of increased emotional competencies resulting from enhanced mindfulness. Because of this, self-reported measures are still crucial in this type of research. Further experimental investigations are needed to provide more definitive evidence.

An interesting observation was from the outlier which was excluded from our analysis as HCC was extremely higher than the average. The data showed a significant decrease in HCC during and after MBSR (from 85.52 to 34.29 pg/mg). At the following interview, the participant reported stressful life events (i.e., the family member has anorexia/depression) during the research period. Although the large change in cortisol for the single outlier participant may not necessarily index increased responsiveness to the intervention, the concept that those with increased ongoing stress may respond more strongly to the intervention is interesting. A previous study found that experience of nature has more influence on restoration in people experiencing greater emotional stress (54). Also, a walk in a natural environment was more advantage to poor mental health group than good mental health group (55). Exploring differential impacts on restoration in people with varying mental health states may be an important direction for further studies.

This study has two main limitations. The major limitation of this study is the inadequate sample size for the overall trial. Another limitation was the absence of control groups, such as those who does not receive MBSR or those who completed a standard 8-week MBSR with all-day retreat. These limitations should be addressed in future studies.

Conclusions

This work provides valuable insights into the combination of potential therapeutic intervention that interact with nature. The "MBSR in nature" as a form of therapeutic intervention could be an effective adjunctive intervention, which could improve public mental health and wellbeing. The findings have applications relevant to clinical settings for the treatment of mental health issues, or where the alleviation of stress, anxiety or pain is a priority. However, the small number of participants who provided hair samples limits the ability to generalise these findings to cortisol, associated with stress; large randomised controlled trials could provide more definitive evidence.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Potential participants were emailed a link to a consent form, a participant information sheet and a baseline questionnaire which they were asked to complete before attending the experiment. The ethical approval for this study was obtained from the University of Sheffield's Research Ethics Committee (reference number 015171).

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Supplementary

Table S1 Participant characteristics by environment

	DASS-21				Hair cortisol			
	All participants (n=99)	Natural outdoor group (n=33)	Built outdoor group (n=33)	Indoor group (n=33)	All participants (n=16)	Natural outdoor group (n=6)	Built outdoor group (n=4)	Indoor group (n=6)
	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)
Age, years	36.35 (5.53)	34.03 (4.50)	34.70 (3.55)	40.33 (6.00)	31.38 (8.16)	32.67 (12.11)	29.25 (4.50)	31.50 (5.96)
Gender								
Male	37 (37.37)	12 (36.36)	13 (39.39)	12 (36.36)	4 (25.00)	2 (33.33)	1 (25.00)	1 (16.67)
Female	62 (62.63)	21 (63.64)	20 (60.61)	21 (63.64)	12 (75.00)	4 (66.67)	3 (75.00)	5 (83.33)
Occupational group								
Undergraduate student	12 (12.10)	5 (15.20)	6 (18.20)	1 (3.00)	2 (12.50)	-	1 (25.00)	1 (16.70)
Postgraduate student	36 (36.40)	16 (48.50)	8 (24.20)	12 (36.4)	5 (31.30)	2 (33.33)	2 (50.00)	1 (16.70)
Staff	51 (51.50)	12 (36.40)	19 (57.60)	20 (60.6)	9 (56.30)	4 (66.67)	1 (25.00)	4 (66.70)

DASS-21, depression anxiety stress scales.

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