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Review article

Exploring the role of exposure to green and blue spaces in preventing anxiety and depression among young people aged 14–24 years living in urban settings: A systematic review and conceptual framework

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ABSTRACT

Despite the growing problem of anxiety and depression amongst young people aged 14–24 years living in urban settings, reviews about the role of exposure to green and blue spaces or nature in preventing anxiety and depression tend to focus on children, adults or sometimes adolescents. This review aims to explore whether exposure to green and blue spaces reduces the risk of anxiety and depression among young people aged 14–24 years living in urban settings and provide a conceptual framework. The academic databases CINAHL plus, Global Health, MEDLINE, ProQuest: Dissertations and Theses, PsycINFO, Scopus and OpenGrey were searched for research published in English between January 2000 and June 2020. All study designs were eligible. All included studies were assessed for quality. Searches identified 9208 sources with 48 meeting the inclusion criteria for the review. Experimental studies provided evidence that walking or being in a green space improves mood and state anxiety immediately following the intervention. Non-randomised evaluations and observational studies suggest that social interaction, physical activity, and mindfulness mediate the relationship between exposure to green space and mental health. We propose that the absence of noise and restorative qualities of green spaces promotes mindfulness and interrupt rumination, which in turn reduce the risk of anxiety disorders and depression. This review and the resulting conceptual framework provide evidence to healthcare professionals about the value of contact with nature and green social prescribing. For policymakers, it provides evidence about the value of bringing the benefits of forests, vegetation and nature into cities, and ensuring that these spaces are accessible and safe for young people to use.

1. Background

Urbanisation is a risk factor for poorer mental health (Krefis et al., 2018). The risks of urbanisation may be mitigated through increasing access to green space (Franklin et al., 2020). Today, 55% of the world's population lives in urban areas, projected to increase to 68% by 2050 (UN Department of Economic and Social Affairs, 2018). Given that 16% of the 7.8 billion world population is aged 15–24 years (Worldometer, 2020) and that millennials make up an ever-increasing proportion of metropolitan areas (e.g. Lee, 2021), we estimate that there are more than 0.7 billion 14–24-year-olds living in urban settings globally. Promoting good mental health in young people is vital as 14% of 10-19 year-olds experience a mental health condition (World Health Organisation, 2021). Young people's mental health is an increasing concern in light of the Covid-19 pandemic (Power et al., 2020), along with access to green space during lockdowns (Slater et al., 2020).

Green space includes dedicated recreational space such as public parks, and other types of green space and vegetation, for example, street trees and green roofs (Hunter et al., 2019). The relationship between green space- and mental health has been demonstrated in several systematic reviews with adults. These show an association between exposure to greenspace and/or outdoor nature-based interventions, and reduced symptoms of stress, depression and anxiety, and increased wellbeing (Houlden et al., 2018; Corazon et al., 2019). Possible mechanisms include improved air quality, physical activity, active travel, connection with nature, cognitive and physiological restoration and social contact (Hartig et al., 2014; Nieuwenhuijsen et al., 2017). Other recently identified potential mechanisms include exposure to

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environmental microbiota (Järbrink-Sehgal and Andreasson, 2020) and biogenic volatile organic compounds (Meneguzzo et al., 2021), and reduced light pollution (Ventriglio et al., 2021). Fewer reviews focus on population subgroups, and none consider differences in relationships between nature and health by sex, ethnicity, or socioeconomic position (Hartig et al., 2014). Regarding children and adolescents, previous systematic reviews have shown beneficial associations between exposure and access to greenspace, and depression and anxiety symptoms, mood, mental well-being, cognitive development, stress and emotional and behavioural difficulties (McCormick, 2017; Tillmann et al., 2018; Vanaken and Danckaerts, 2018; Zhang et al., 2020). These reviews are limited by not seeking to clarify the extent to which research has explored if and how green space can reduce the risk of developing clinical levels of anxiety and/or depression. Furthermore, reviews have not focused on young people aged between 14 and 24 years. This age range is of great interest as most mental health conditions develop during these years (Kessler et al., 2003). There is also an increasing research interest in examining the health and wellbeing benefits of "blue spaces" - which can be defined as 'all visible surface waters' (Völker and Kistemann, 2011) including rivers, streams, ponds, lakes and coastal waters - for reducing anxiety and depression amongst children and young people (Reece et al., 2021), but reviews including blue spaces do not focus on the age range of interest (Gascon et al., 2015).

The use of psychological theory to understand links between mental health and green and blue spaces has been limited for children and adolescents (Vanaken and Danckaerts, 2018). Previous literature reviews focusing on younger people refer to theories developed in relation to adults (Zhang et al., 2020). However, existing theoretical frameworks note that age is likely an important factor in understanding how access to green and blue spaces might influence mental health (Nieuwenhuijsen et al., 2017; Markevych et al., 2017). Although Attention Restoration Theory has been cited in relation to work with younger people (Gascon et al., 2015), there is a lack of theoretical underpinning for the development of interventions in relation to exposure to green and blue space and how this operates to impact mental health. It is vital to explore what types of green and blue spaces may be linked to mental health, and to better understand from the literature the mediating pathways and mechanisms. This will inform the development of conceptual frameworks in this area that relate specifically to this age group.

Our earlier scoping review (Reece et al., 2021) described the state of the evidence base for exposure to green and blue space to reduce the risk of anxiety and depression among young people living in urban settings. It found that the literature included both observational (34%) and experimental designs (28%). A very wide range of exposures were evaluated (e.g. urban green space, contact with nature). Importantly, few studies had clinical levels of anxiety or depression as the outcome. Instead, broader terms for mental health which can be related to, or precursors of, anxiety and depression were more common in the literature. This highlights that the current literature does not focus on studies that demonstrate the extent to which prevention of clinical disorder is achieved. Rather, they focus on reduction of risk and pre-clinical distress.

The scoping review informed this systematic review. Here we take a novel and empirical approach to examining the evidence about the role of exposure to green and blue spaces in preventing depression and anxiety in young people aged 14–24 years living in urban settings, and the pathways involved. We build on the conceptual framework provided by Hartig et al. (2014) and refined by Nieuwenhuijsen et al. (2017) but focus specifically on anxiety and depression in young people. This framework includes measures of green space (e.g. neighbourhood vegetation, access to green space), exposure to green space (e.g. frequency and duration of use), possible mechanisms to achieving health outcomes (e.g. environmental exposure, physical activity, social contacts and cohesion, biogenics, and restoration and stress reduction), and health and wellbeing outcomes (Fig. 1). Nieuwenhuijsen et al. (2017) summarise the relative strength of evidence across the mechanisms, and emphasise that studies often measure either mechanisms (e.g. physical activity) or the health and wellbeing outcomes.

For the purposes of this review, our definition of exposure to green space encompasses (i) access to urban green spaces such as parks, or vegetation (for example, as measured by the normalized difference vegetation index (NDVI; Ekkel and de Vries, 2017) and (ii) exposure through activities or interventions that take place in green or natural environments (e.g. walking or adventure training) and (iii) simulations of green or natural environments (e.g. recorded sounds of nature). We also include 'blue space' (such as lakes), although this field of research is more recent (Reece et al., 2021).

Following Wolpert et al. (2019), we use a broad definition of anxiety and depression, including self-report of stress or low mood. We include studies that focus on primary prevention, when the aim is to prevent anxiety or depression from developing in the first place, as well as studies of secondary prevention, which aims to reduce the impact of anxiety and depression early once it has developed. Prevention of depression and anxiety can be thought of as reduction in symptoms of these "disorders" that disrupt functioning (Kutcher et al., 2015; Lawrence et al., 2017), or as a reduction in processes associated with anxiety/depression (such as stress, rumination or lack of positive activity) or improvements in mental wellbeing (O'Connell et al., 2009). For example, in young people, experiences of sub-clinical levels of low mood are strongly linked to greater risk of developing major depressive disorders (Davey and McGorry, 2019). We therefore included these broad terms to identify studies that may improve mental health or reduce sub-clinical symptoms of mental "disorder", as indicating reduction in risk of anxiety and depression (Kutcher et al., 2015). As such, interventions that reduce low-mood may reduce risk and increase prevention of depression. Similarly, stress reduction focused interventions form part of the prevention initiatives for both depression and anxiety (Brown et al., 2019).

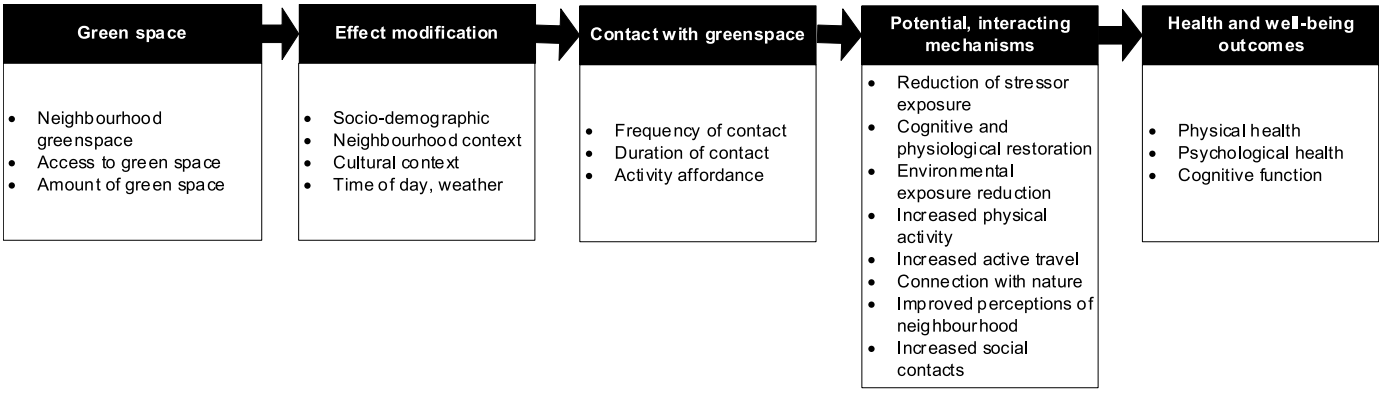

Fig. 1. Socio-ecological framework for the relationship between greenspace and health and well-being (adapted from Nieuwenhuijsen et al., 2017).

The inclusion of secondary as well as primary prevention is appropriate, given the high prevalence of anxiety and depression amongst young people and the need to explore the mechanisms through which green space can impact on health and wellbeing (Nieuwenhuijsen et al., 2017). We did not include tertiary prevention, that is studies of clinical samples that are not representative of the general population.

Rather than conducting a traditional systematic review with narrow inclusion criteria (e.g. focusing on specific mechanisms or mental health outcomes), we sought to include a wide range of evidence from different disciplines and using any study design, in order to understand causal mechanisms and develop a conceptual framework.

2. Methods

2.1. Specifying the research question and search strategy

Our research question was "*Does exposure to green and blue space reduce the risk of anxiety and depression among young people aged 14–24 years living in urban settings and, if so, what are the causal mechanisms?*" We aimed to search for evidence about a wide range of exposures, outcomes and study designs, and to then select studies which would address each aspect of the research question, including mechanisms.

Key terms for three main concepts were created and used in the literature search: population, exposure, and outcome. Medical Subject Headings (MeSH) were also used where possible. The search terms and strategy for each database can be found in Supplementary Material. The protocol was not registered due to time constraints.

2.2. Database searches

The following databases were searched; CINAHL plus, Global Health, MEDLINE, ProQuest: Dissertations and Theses, PsycINFO, Scopus and OpenGrey. All databases were searched in July 2020. The searches in databases; CINAHL plus, MEDLINE, ProQuest: Dissertations and Theses, PsycINFO, and Scopus, were last updated 6th July 2020. Global Health and OpenGrey were searched 7th July 2020. Further relevant studies were added from reference lists of previously published systematic reviews (McCormick, 2017; Tillmann et al., 2018; Vanaken and Danckaerts, 2018; Zhang et al., 2020). We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009).

2.3. Selecting the evidence

We included sources from any country, published between 2000 and July 2020, written in English, and of any study design (including systematic reviews, experimental, observational and qualitative). For studies to be eligible for inclusion, (i) at least half of the participants had to be within the target age range (14–24 years) old, or (ii) at least half of the participant age-range had to overlap with this age range, or (iii) the reported mean or median age had to be within this age range. Participants had to be living in urban settings. We included studies that explored both access to green and blue spaces, including those in rural settings accessed by urban populations (e.g. forests), and contact with green space through activities or interventions that take place in these environments (e.g. running, walking). We also included components of being in these environments (e.g. sounds, sights, smells), and built environments that could include green components (e.g. street trees). The outcome measures we included were anxiety and depression, as well as those psychological variables which may provide insights into the mechanisms associated with anxiety and depression. These included mood, life satisfaction, happiness, wellbeing, and quality of life. In order to answer our research question and refine the conceptual framework developed by Nieuwenhuijsen et al. (2017), papers reporting on potential additional mechanisms such as connectedness to nature, mindfulness, physical activity, social cohesion, and self-esteem, were also included. We excluded sources published before 2000 and not published in English. Participants in exclusively rural settings or diagnosed with other mental health or developmental conditions (e.g. addiction, behavioural problems, autism) and other clinical samples (e.g. children or young people diagnosed with diabetes) were excluded. We excluded sources focused on athletes or competition-level sport, treatment or management of mental health outcomes, and exclusively physiological outcome measures.

The lead author carried out the title screening supported by Mendeley software. Full-text screening was carried out by four authors in Mendeley and Excel. Following screening, a list of included sources was transferred into an Excel spreadsheet for data charting. Data charting was carried out by four authors. We charted the authors of the source, title, journal, year of publication, source type, country of publication, whether the country was developed or developing, study design, population age, general or clinical population, intervention/exposure type, the outcome measure and whether that included anxiety and depression, or potential mechanisms. These potential mechanisms included stress, wellbeing, quality of life, mood, and mental health/illness/condition/disorder. A broad range of evidence was required to refine the existing conceptual framework. We therefore assessed eligible studies against four key inclusion criteria. (If we had simply applied stricter inclusion criteria with respect to age, study design, exposure or outcome, this would not have allowed us to explore the mechanisms and modifiers in the conceptual framework). These criteria (C) were chosen to select sources most relevant to our original aims, while retaining breadth of evidence. They related to: the population of interest (C1: all participants within the 14–24 years age range), study design (C2: an experimental study design, including before-and-after studies, to assess effectiveness), exposure (C3: access to, or contact with, urban green space) and primary outcome (C4: assessing anxiety and/or depression). Studies were selected for inclusion if they met at least two of these criteria. For example, the relationship between access or contact with urban green space (C3) and mood in a sample of only 14–24-year-olds (C1), or an experimental study (C2) which involved taking participants, of whom 50% were aged 14–24 years, to a forest and measuring their anxiety (C4).

2.4. Data extraction and quality assessment

Variables extracted for each included study were authors, year of publication, location of study (country), sample (age, sex, other characteristics), study design, exposure (or intervention) and how this was measured, results relevant to our outcomes of interest and any information regarding mediating factors or mechanisms.

Quantitative sources were assessed for quality, including risk of bias, using the Effective Public Healthcare Panacea Project's Quality Assessment Tool for Quantitative Studies (Effective public healthcare, 2020). EPHPP evaluates selection bias, study design, confounders, blinding, data collection method, withdrawals and dropouts as being 'weak', 'strong' or 'moderate'. The EPHPP provides a global quality rating for each study of 'strong' (no weak ratings), 'moderate' (one weak rating), or 'weak' (more than one weak rating). We also derived a summary score for the number of criteria scored as 'Strong' in each study. The EPHPP is considered suitable to assess the quality of a wide range of quantitative study designs, including interventions (Jackson and Waters, 2005; Deeks et al., 2003). The EPHPP has excellent inter-rater reliability for overall scores (when compared to the Cochrane Collaboration Risk of Bias Tool) (Armijo-Olivo et al., 2012). It also has good construct and content validity (Jackson and Waters, 2005). For other study designs, CASP tools were used (CASP, 2018) to create a similar summary score for quality assessment. For example, the CASP qualitative tool produces a quality rating for each study from the assessment of nine closed questions relating to rigour, credibility and relevance, and is widely used for quality assessment in systematic reviews (Dixon-Woods et al., 2007). Two researchers completed quality assessments and data extractions for

each paper, with benchmarking between each pair of assessors. If the global score differed, this was discussed until agreement was reached. Given the broad range of disciplines that we intended to include in our review, we did not use the quality scores to exclude studies, but did consider these in the synthesis of results and development of the conceptual framework.

2.5. Data synthesis and development of conceptual framework

Given the wide range of study designs and outcome measures (e.g. difference in means, incidence rate ratio) including qualitative outcomes, a narrative approach to data synthesis was adopted rather than meta-analysis. This included an analysis of variability in terms of setting, population, exposure/intervention, and outcomes (Popay et al., 2006). The included studies are organised into six groups based on type of exposure.

We tabulated the characteristics of each paper, including the exposure, outcome measure, results, and information from each paper about possible mediators or causal pathways, along with a summary quality score. Initial synthesis for each group of studies was undertaken by the primary reviewer in regular discussion with other members of the team. The synthesis gave greater weight to higher quality evidence.

This information was used to build on the conceptual framework from Nieuwenhuijsen et al. (2017), describing potential causal mechanisms linking exposure to green spaces to anxiety and depression, including possible intermediary psychological processes. The preliminary conceptual framework (Nieuwenhuijsen et al., 2017) was based on categories for exposure to green spaces on the one hand (e.g.

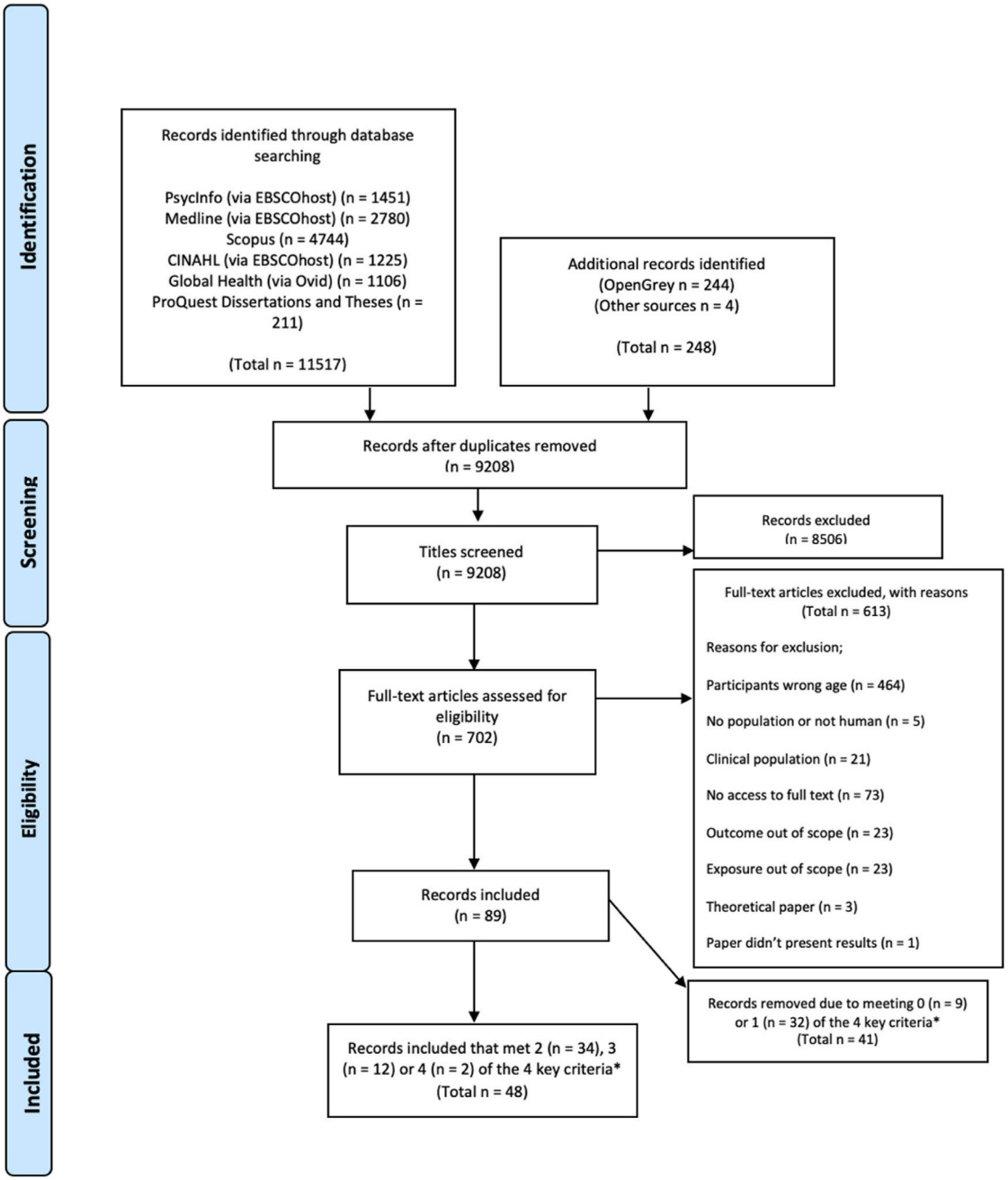

Fig. 2. Flow diagram of literature search and selection (following PRISMA guidelines).

exposure to parks), and the psychological effect (anxiety and depression) on the other. While there were few studies that used anxiety disorders or clinical depression as outcomes, many studies included symptoms or pre-cursors such as mood and state anxiety. The second stage was therefore to add in these mechanisms to the framework. We had also extracted data on other mechanisms reported in the Nieuwenhuijsen et al. (2017) framework. These included behaviours (e.g. physical activity) and environmental factors (e.g. noise) that had been related to green spaces, and which contributed to the causal pathway. A small number of studies included information on perceptions of these spaces (e.g. danger), which modified these associations. The final step was to ensure the framework linked green spaces with these behavioural, environmental and psychological mechanisms and then to the psychological outcomes of anxiety and depression. Each component of the framework was reviewed by the inter-disciplinary team, and by a PPI panel of seven young people with lived experience of anxiety or depression. Finally, we summarise the available evidence for different subgroups of the population of interest.

3. Results

After removal of duplicates, we screened 9208 titles and abstracts. 702 sources were eligible for full text screening (Fig. 2). After further exclusions (76% of which were due to the age range not being relevant), 89 sources remained. The 89 sources were considered against four key criteria (C1–C4), relating to the population of interest, study design, exposure and outcome, as described in the Methods. Forty-eight sources met at least two of these criteria and were included in the review.

3.1. Description of included studies

3.1.1. Study location

Of the 48 studies, 46% were located in Asia, including Japan (21% of all included studies), China, Taiwan, Indonesia, Turkey and Iran. Just over one quarter of studies were conducted in Europe (27%), including the United Kingdom, Germany, Austria, Switzerland, France, the Alps, Bulgaria, Czech Republic, Sweden, and Norway. Some studies were located in North America (19%), with 7 studies from the United States and two from Canada. Three studies were based in New Zealand and one study in South Africa. No studies were located in South America.

3.1.2. Sample population

Over half (58%) of the studies included in this review had a sample population of university students. Of the 48 studies, 8 (17%) had a sample population of adults which overlapped with the target age range (14–24 years). Some of the studies focused on students in high school education (15%), and two studies included youth participants (4%). Lastly, some studies had a mixed sample of university students and staff (4%) and university students and graduates (2%).

3.1.3. Environment exposures

A wide range of environments were represented in the included studies. The largest proportion reported exposure to greenspaces through being in forests, including bamboo forests (21%). Other types of green space exposure included parks, sports fields, botanical gardens, horse trekking through fields and forests, outdoor employment in greenspaces, and generally being outdoors in a green space. Only three studies reported NDVI as a measure of exposure to green space. Some of the experimental conditions involved participants being near an indoor plant or touching natural materials (such as wood). Several of the studies used simulated exposure to nature. These studies involved participants listening to recorded soundscapes of natural sounds, or images of nature such as scenes of forests, mountains, water, wilderness, gardens, and agricultural landscapes. Two studies included used videos of outdoor environments and green spaces as simulated exposure to nature. Other studies included evaluations of outdoor adventure programs situated near lakes and mountains, as well as outdoor rock climbing. Exposure to blue spaces was also represented with some studies evaluating interventions such as canal walkways and sailing on the ocean.

3.1.4. Outcome measures

There were a wide range of outcomes measured and several studies used more than one. Outcomes ranged from measures of mood/affect and stress/anxiety experiences, closely linked to the concepts of clinical anxiety and depression. Further measures assessed constructs that may support the prevention of anxiety and depression, for example mechanisms of mindfulness, motivation, self-determination and self-efficacy. Measures of more general mental wellbeing outcomes were common, such as life satisfaction and wellbeing.

3.1.5. Study design

The majority of studies (n = 47, 98%) were quantitative. These included randomised trials (n = 18), and non-randomised intervention studies (n = 18), cohort studies (n = 5) and cross-sectional surveys (n = 6). While some of these studies included qualitative elements, only one purely qualitative study was included.

3.2. Quality assessment

Assessment of publication bias via a funnel plot was not possible due to the heterogeneity of studies. Quality scores are reported for each paper in Tables 1–6. There was strong initial agreement between the reviewers for global quality scores for the 47 quantitative studies (90%). Overall, areas of strength identified included approaches to dealing with confounders, use of validated outcome measures and low drop-out. This low attrition reflects that very few studies did follow-up post-intervention. Other areas in which quality was not generally highly rated were in representativeness of the sample (e.g. response rates were not reported), and blinding. This is important given the self-reported nature of outcomes. Quality scores were higher on average for those studies which compared urban streets with urban parks and forests, which were all experimental (mean score 3.1/6), and studies that compare physical activity in a green/blue environment and indoors, or evaluate physical activity programmes, which were also intervention studies (mean score 2.8/6). The studies which evaluated outdoor adventure programs, and education/training/employment in green environments, had a mean score of 2.3/6 for the quantitative studies and included one high quality qualitative study (scoring 7/9). Of lower quality were the studies which assessed particular aspects of being in green/blue environments (mean score 1.4/6). These were particularly weak on selection bias and reporting blinding. Also, the observational studies of residential exposure to vegetation, which tended to be cross-sectional (mean score 2.2/6), and the studies about young people's perceptions of green spaces (mean score 2.0/6) had lower quality scores.

3.3. Evidence synthesis

3.3.1. Studies that compare urban streets, urban parks and forests

Thirteen of the studies described experimental designs that compared (walking or being in) urban settings with neighbourhood green space or forests (Table 1; scales used to measure outcomes are listed in Supplementary Material). Over the last 10 years a body of research has developed comparing exposure to forests and urban environments (Lee et al., 2011, 2014; Mao et al., 2012; Tsunetsugu et al., 2013; Song et al., 2018, 2019; Lyu et al., 2019; Zeng et al., 2020; Hassan et al., 2018). This has been complimented in more recent years by studies on urban parks (Franek, 2013; Wallner et al., 2018; Song et al., 2014, 2015). The majority of interventions were for 15 min (Tsunetsugu et al., 2013; Song et al., 2014, 2015, 2018, 2019) but ranged up to three days (Lee et al., 2011; Lyu et al., 2019. These experimental studies measured outcomes immediately after the intervention. They provide evidence that a brief exposure to a green environment elicits a

Table 1
Main characteristics and results of studies that compare urban streets, urban parks and forests.

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/ mechanisms	QA[b]
Franek, 2013	Czech Republic	4 studies using psychology undergraduat es. Age range across studies = 19.6–20.7 yrs.	Repeated measures experimental designs and one study is an observational survey.	Walking routes with and without greenery.	Walking speed measured in all studies. Study 4 measured emotional reactions using model by Mehrabian and Russell.	Significant effects of type of section on perceived emotional reactions on the environment: pleasure $p < 0.001$, arousal $p < 0.001$, dominance $p < 0.001$. Significant effects of type of section on perceived fascination $p < 0.001$, being away $p < 0.001$, compatibility $p < 0.001$, coherence $p < 0.001$.	Study 4 investigated potential causal pathways for Studies 13, with environmental factors affecting participants desire to leave.	2
Hassan et al. (2018)	China	60 university students (50% male). Mean age = 19.6 yrs.	Randomised crossover trial.	15 min walk predetermined courses in a bamboo forest and a city area (control).	Semantic differential method (SDM), State-Trait Anxiety Inventory (STAI).	Significantly higher scores were observed for the adjectives "comfortable," "relaxed," and "natural" ($p < 0.01$) after walking in the bamboo forest than after walking in the city area. Total state anxiety scores were significantly reduced after bamboo forest walking compared with the city area walking (bamboo forest: 35.0 ± 7.39 and city area: 41.9 ± 9.78; $p < 0.01$).	Blood pressure was significantly reduced – relaxing effect.	3
Lee et al. (2011)	Japan	12 healthy students. Male only. Mean age = 21.2 yrs.	Randomised crossover trial.	3-day intervention involving viewing a broad-leaved forest or an urban environment for 15-mins each day.	Profile of Mood States (POMS).	Significant differences were found between the forest and urban sites for the tension-anxiety subscale (forest: 42.4 ± 1.5; urban: 61.8 ± 3.4; $p < 0.01$).	Forests have a positive effect on autonomic nervous system and reduces salivary cortisol. Sympathetic nervous system suppressed in the forest.	3
Lee et al. (2014)	Japan	48 Japanese participants. Male only. Mean age = 21.1 yrs.	Randomised controlled trial in 4 different prefectures with 12 participants in each. 2 groups of 6 completed intervention and control.	Self-paced walking in forest or urban environment for ~12–15 min.	STAI, POMS - Shortened Version, 13-scale questionnaire using SDM, measure of feeling 'refreshed'.	STAI levels were largely decreased after forest walking (33.2 ± 6.9) compared with after urban walking (45.2 ± 8.9; $p < 0.01$). After forest walking, significantly decreased values were found in POMS subscale of tension-anxiety (T-A, 35.6 ± 4.0 at the forest site and 41.6 ± 7.6 at the urban site; $p < 0.01$). Significantly higher scores were observed for the "refreshed" feeling after forest walking (65.5 ± 10.7) compared with those for urban walking (50.4 ± 13.2; $p < 0.01$).	Forest walking significantly increased parasympathetic nervous activity and decreased sympathetic nervous activity compared with urban walking. Forest-oriented stimulations facilitate the relaxation of central and autonomic nervous activities to suppress the secretion of stress hormones.	3
Lyu et al. (2019)	China	60 healthy university students. Male only.	Randomised controlled trial. Participants either exposed to a	Bamboo forest therapy program in a bamboo forest or exposure to an	POMS.	Scores of negative moods for tension-anxiety, depression-dejection, fatigue,	Systolic blood pressure was significantly lower after a three-day bamboo forest therapy session. The	4

(*continued on next page*)

Table 1 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/ mechanisms	QA[b]
		Mean age = 21.8 yrs (experimental group), 21.6 yrs (control).	bamboo forest (3 groups of 15 participants at different forest settings) or an urban environment (1 group of 15 participants)	urban environment over the course of 3-days.		confusion and anger-hostility significantly decreased after the bamboo forest program ($p < 0.05$). No difference was found in the scores of any of these negative moods after the urban program.	SpO2 (peripheral oxygen saturation) of participants was higher after the bamboo forest program than before the program.	
Mao et al. (2012)	China	20 healthy university students. Male only. Mean age = 20.79 yrs.	Randomised controlled trial. Participants divided into 2 groups of 10.	2 walking trails for 1.5 h (with 10 min break) through a forest or an urban site.	POMS.	For the forest bathing condition, the scores in the negative subscales, such as tension, depression, anger, fatigue, and confusion, were lowered ($p < 0.05$); however, the positive score for vigour was increased.	Serum cortisol concentration was significantly lower in subjects exposed to a forest environment than in those exposed to an urban environment. These findings indicate that subjects staying in a forest environment showed a reduced stress response.	3
Song et al. (2014)	Japan	17 Japanese students. Male only. Mean age = 21.2 yrs.	Within subject's design. Participants completed the walking course in an urban park and city environment.	15 min predetermined walking course in an urban park compared with nearby city area.	STAI, POMS.	Total STAI score was 14.3% lower after the urban park walk compared with that after the city area walk (urban park: 41.6. ± 7.0 (mean ± standard deviation), city area: 48.6 ± 6.3; $p < 0.05$). Scores for the negative subscales of POMS tension-anxiety and fatigue were significantly lower after walking in the urban park than after walking in the city area ($p < 0.05$). There were no significant differences in the scores for depression, anger-hostility, and confusion.	The physiological measures suggested a beneficial effect of walking in an urban park, similar to that expected from a forest setting/ yoga/massage, which may explain the psychological outcomes.	2
Song et al. (2015)	Japan	23 university students. Males only. Mean age = 22.3 yrs.	Controlled clinical trial. Participants took part in both conditions.	15 min walking through an urban park and 15 min walking through the city.	SDM, STAI, POMS.	Significantly higher SDM scores were observed following the urban park walk than those following the city area walk for the following three adjectives: "comfortable", "natural", and "relaxed" ($p < 0.01$). The total STAI score was 19.3% lower after the urban park walk than after the city area walk (urban park: 39.0 ± 6.3; city area: 48.4 ± 7.5; $p < 0.01$). Differences were also detected in the POMS scores for the negative subscales of tension–anxiety, anger–hostility, fatigue, and confusion being significantly lower after walking in the urban park than	No significant differences in walking speed. The intervention induced physiological relaxation. Compared with those after a brief walk in the city area, parasympathetic nervous activity was significantly enhanced, sympathetic nervous activity was significantly suppressed, and heart rate was significantly lower during a brief walk in the urban park.	3

(*continued on next page*)

Table 1 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/ mechanisms	QA[b]
						after walking in the city area ($p < 0.05$).		
Song et al. (2018)	Japan	585 Japanese participants. Males only. Mean age = 21.7 yrs.	Randomised cross-over trial on 2 consecutive days. Control was a walk in an urban environment.	15 min forest walk or city walk.	STAI, POMS - shortened version.	Scores for tension-anxiety subscale on POMS were significantly lower after walking through forest areas compared to city areas (forest, 36.1 ± 5.4; city, 41.3 ± 7.7; $p < 0.01$).	Participants with high-trait anxiety levels had a more effective reduction in the feeling of depression–dejection after walking through forest areas compared with those with normal and low-trait anxiety levels (participants with high-trait anxiety, N = 325; participants with normal and low-trait anxiety, N = 260; $p < 0.05$).	4
Song et al. (2019)	Japan	60 Japanese students. Females only. Mean age = 21 yrs.	Randomised controlled trial with 12 participants at each site (6 sites total). Cross-over trial on 2 consecutive days.	15 min walk in a forest area and city area.	STAI, POMS.	The state anxiety score of the STAI was 34.8 ± 7.2 after walking in a forest area, significantly lower than 45.3 ± 7.1 after walking in a city area ($p < 0.01$). Participants felt significantly more "comfortable," "relaxed," and "natural" when walking in forests than when walking in city areas (all $p < 0.01$). Significant differences between the forest and city areas were observed for all the POMS subscales rated after walking and for the total mood disturbance score. The subscale scores for the tension-anxiety subscale in forest and city areas were 1.1 ± 1.8 vs. 2.9 ± 2.8.	Walking in a forest was associated with significantly higher parasympathetic nervous activity and lower sympathetic nervous activity and heart rate.	4
Tsunetsugu et al. (2013)	Japan	48 Japanese participants. Males only. Mean age = 21.1 yrs.	Randomised cross-over trial over 2 days.	Viewing 4 forest sites from a seated spot for 15 min compared with urban site.	POMS, 13-scale questionnaire using SDM techniques, Measure of feeling 'refreshed'.	For the POMS scores, viewing the scenery in the urban areas increased tension-anxiety ($p = 0.00$). The landscapes of the forests were evaluated as being significantly more "comfortable" ($p = 0.00$, $r = 0.51$), "soothing" ($p = 0.00$, $r = 0.53$), and "natural" ($p = 0.00$, $r = 0.59$). Viewing the scenery in the forests induced significantly higher refreshment ($p = 0.00$, $r = 0.55$).	Physiological outcomes agreed with psychological outcomes. Suggests forest areas have positive effects in terms of relaxation. Just viewing forest landscape, not necessarily walking, has positive effect on mood and anxiety.	3
Wallner et al. (2018)	Austria	60 healthy pupils from 3 schools in Vienna. Mean age = 16.6 yrs. 30 males, 30 females.	Repeated measures controlled trial.	Exposure to 3 different settings at lunchtime with 7 days in between each. Settings included an inner urban small park, a larger park with some trees, and a large forest.	Wellbeing measured using The Nitsch Scale, cognitive performance test.	Significant differences between 3 green space types for dimensions recuperation, tension/relaxation, state of mood, readiness for action, and readiness for exertion.	Findings may support stress reduction and attention restoration theories.	3

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Table 1 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/ mechanisms	QA[b]
						For forest, significantly less decrease of wellbeing after return to classroom compared to small or large urban park (readiness for action: $p < 0.001$; readiness for exertion: $p = 0.027$; state of mood: $p < 0.001$; tension/relaxation: $p < 0.001$). Concentration performance (d2-R test) significantly higher after green space exposure for all sites ($p < 0.001$). Increase post small urban park 7.5 (SD 9.7), post large urban park 15.5 (SD 11.7), post forest was 5.3 (SD 11.0). Highest performance increase found for large park; this increase was significantly higher ($p = 0.008$) than the increase after stays in the other green spaces.		
Zeng et al. (2020)	China	120 university students aged 19–24 yrs. 60 males, 60 females. (15 males and 15 females in each group).	Randomised controlled trial. Participants divided into 4 groups and exposed to 1 of 4 environments.	Viewing (15 min in morning) and walking (15 min in afternoon) in a bamboo forest or urban environment.	SDM.	Following the three-day bamboo forest therapy, participants showed a significant difference in their environmental evaluation (SDM) relative to those at the urban city site. In terms of sensory perception, atmosphere, climate, place, and space, the subjects reported a better environmental experience in the bamboo forests.	Physiological indices supported the SDM questionnaire results.	3

[a] References for measures are given in Supplementary Material

[b] Quality assessment score out of 6; POMS: Profile of Mood States; POMS: Profile of Mood States – Shortened Version; SDM: semantic differential method; STAI: State-Trait Anxiety Inventory.

short-term increase in mood and reduction in state anxiety. One study reported longer-lasting effects following exposure to a forest than a park (Wallner et al., 2018) and estimated reductions in state anxiety are greater following visits to forests (Lee et al., 2011; Song et al., 2019) than parks (Song et al., 2014, 2015).

3.3.2. Studies that assess particular aspects of being in green/blue environments

A further eight intervention studies (two of which were randomised) assessed particular aspects of being in green or blue environments and reported some positive changes in various outcome measures (see Table 2). The aspects considered were the colour green (Akers et al., 2012), natural soundscapes (Benfield et al., 2014; Tedja and Tsaih, 2015), natural scenery (Chang et al., 2008; Chan KLE, 2015), touching natural materials (Ikei et al., 2018), indoor exposure to plants (Buttelmann and Römpke, 2014 and to animals (Hassan et al., 2017), Levels of anger were lower when viewing green (compared with red) scenery (Akers et al., 2012), listening to natural sounds was shown to be more restorative than anthropogenic sounds (Benfield et al., 2014), and touching wood induced feelings of comfort (compared with marble; Ikei et al., 2018). The interventions were typically brief (e.g. 5 min) and outcomes were measured immediately after the intervention.

3.3.3. Studies that compare physical activity in a green/blue environment and indoors, or evaluate physical activity programmes

Three experimental studies compared exercise in a green or blue environment with doing the same exercise indoors (Table 3). The first intervention was a walking route (approximately 17 min) along a canal (Nistbet and Zelensji, 2011). Compared to an indoor walking route, this led to increased connectedness with nature, mediated by positive affect. It also showed that participants tended to underestimate the positive hedonic effects of the outdoor walk. The second involved cycling on a static bike on the edge of a green field for 15 min and found greater increases in vigour, but not self-esteem, when exercising in the green

Table 2
Main characteristics and results of studies that assess particular aspects of being in green/blue environments.

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
Akers et al. (2012)	UK	14 healthy participants. Males only. Mean age 20.7 yrs.	Randomised controlled trial. Within subjects.	5 min simulated cycling whilst viewing outdoor environment video in various colours.	Profile for Mood States (POMS).	No differences reported for anxiety or depression subscales of POMS. Anger was higher during red colour video compared to green (38.6 ± 1.3 vs 37.0 ± 0.0, t13 = 4.6, p = 0.0005, η2 = 0.619, d = 1.741) and compared to grey (38.6 ± 1.3 vs 37.1 ± 0.5, t13 = 4.0, p = 0.001, η2 = 0.552, d = 1.523).		3
Benfield et al., 2014	USA	133 university participants. 72 females, 61 males. Mean age = 19.09 yrs.	Randomised controlled trial. Participants assigned to 1 of 4 conditions.	Watching a stress inducing video followed by listening to a soundscape (either natural sounds, natural sounds with voices, natural sounds with motorized noise, or no sound as a control).	Brief Mood Introspection Scale (BMIS).	Significant BMIS change by sound condition was shown for Pleasant-Unpleasant sub-scale (F = 7.62, p < 0.001, partial η2 = .150) and Positive-Tired subscale (F = 6.36, p < 0.001, partial η2 = .126); a marginal interaction between sound condition and affective restoration was also shown for the Negative-Relaxed subscale (F = 2.18, p = 0.094, partial η2 = .048). The natural sound condition showed greater recovery from the upsetting video compared to both the control and anthropogenic sound conditions. For the Pleasant-Unpleasant score, participants in the natural condition were the only ones to show improved affect from post video (M = 38.89, SD = 8.22) to post-recovery (M = 44.31, SD = 6.95).		2
Buttelmann and Römpke (2014)	Germany	71 undergraduate students. 65 females. Mean age = 22 yrs, range = 18.8–29.8 yrs.	Controlled trial. Participants allocated to 1 of 4 conditions.	Sitting in a room with either a dog, fish, plant or nothing (control) for 5 min.	State-Trait Anxiety Inventory (STAI) – German adaptation, Pet Attitude Scale (PAS), Audience Anxiousness Scale (AAS).	A reduction effect was found in all three experimental conditions: in the fish group, induced anxiety was reduced on average by 58.2%; in the dog group by 56.2%; and in the plant group by 45.6%. There were significant differences in the decrease in induced anxiety between groups (one-way ANOVA, F (3,67) = 8.232, p ≤ 0.001, np[b] = 0.271). Engaging in contact with a dog, a fish, or a		1

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Table 2 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
						plant for an intervention time of no longer than 5 min can result in anxiety alleviation in a non-clinical setting.		
Chan KLE, 2015	China	'Mostly young students' (study 1) and 'mostly healthy students and staff' (study 2). Study 3 (patients and relatives) are excluded.	Within subject's design.	Viewing nature videos on a PC screen. Videos of water, forest, mountains, sunrise, sunset. Experiencing coloured lights in a tent.	Relaxation level as measured on a 5-point self-report scale.	The majority reported a positive relaxing effect after viewing the films; 89% scored the relaxation effect of watching the natural films as fairly strong/ strong. Most common descriptors were 'relaxing' (33%), followed by 'comforting' (15%). The most relaxing colours were green (15/65 = 23%), purple (20%), blue (17%). The least relaxing colours were red (31/ 62 = 50%), blue (18%), green (7%).		0
Chang et al., 2008	Taiwan	110 participants – students and faculty members from a university.	Within subjects.	Viewing 12 images on a screen, 10 s each. E. g. mountain, wilderness, gardens, sunset, view from window, water.	Perceived Restorativeness Scale (PRS).	Viewing natural environments with features of 4 restorative components improved psychological responses. The images ranked first on the PRS Fascination component and second on Compatibility. The images proposed as examples of the four restorative components were generally rated as hypothetically selected, although not cleanly enough to be treated as representing those components.		2
Hassan et al., 2017	China	40 healthy agricultural university students. 20 males. Mean age = 19.6 yrs.	Controlled trial.	Viewing a bamboo plant in a room vs viewing an empty pot (control).	STAI.	Participants' mean anxiety score decreased after viewing the bamboo plant compared with control ($p < 0.01$). STAI score females, bamboo view: 32.7 ± 6.7; control view: 37.9 ± 7.4. STAI score males, bamboo view: 34.0 ± 6.7; control view: 39.2 ± 7.1.	Viewing a plant indoors can lower blood pressure which in turn help to can reduce anxiety - links to the autonomic nervous system.	1
Ikei et al., 2018	Japan	19 healthy female university students. Mean age = 21.2 yrs.	Within subjects.	Touching wood (experimental) or marble (control) slabs with soles of feet.	Semantic differential method (SDM).	Participants feeling "slightly comfortable" after touching Hinoki and "indifferent to slightly uncomfortable" after touching marble. Touching Hinoki induced significantly more comfort than	Increases in parasympathetic activity shown. Physiological relaxation effects shown when touching the wood.	2

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Table 2 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
						touching marble ($p < 0.01$).		
Tedja and Tsaih, 2015	Taiwan	66 architecture university students. Mean age = 20.25 yrs. Age range 18–33.	Within subjects.	Listening to 15 s soundscape videos. Sounds were of indoor and outdoor water sounds.	Participants rated perception/emotion. Scales divided into attractiveness and serenity. One of the sub-scales for serenity was 'anxious-peaceful' – participants had to rate on a 7-point bipolar scale. (e.g. −3 = anxious, 3 = peaceful, 0 = middle point).	92% of the participants had a positive impression of a soft, quiet, and mid frequency sound (gentle stream) due to the listening impression of relaxation and comfort. 77% of the participants had a negative impression of a loud, intense, and broadband sound (rain on glass roof), due to the listening impression of noisiness and agitation. 62% of the participants preferred the sound of rain on water due to the listening impression of quiet over rain on different materials such as woods, metal, glass, tent, and pavement.	Gentle stream and fountain noises can be used for restoration and relaxation.	0

[a] References for measures are given in Supplementary Material.
[b] Quality assessment score out of 6. AAS: Audience Anxiousness Scale; BMIS: Brief Mood Introspection Scale; PAS: Pet Attitude Scale; POMS: Profile of Mood States; PRS: Perceived Restorativeness Scale; SDM: semantic differential method; STAI: State-Trait Anxiety Inventory – German Adaptation.

environment (Flowers et al., 2018). The third paper compared horse-trekking for 30 min in a green environment with riding on an indoor simulator. This involved contact with the animal as part of the intervention. and the authors reported improvements in feelings of anxiety and depression (Matsuura et al., 2011). Two further randomised trials assessed reported improvements in mood and sleep (Kalak et al., 2012; Walter et al., 2013) following outdoor running programmes. One involved running twice a week for ten weeks for 30–60 min, the other five times a week for three weeks for 30–37 min. A before-and-after study reported reductions in social anxiety following a two-month climbing programme (three times a week; Ozen, 2015). Finally, one study compared the effects of doing 15 min outdoor exercise on mood in an induced goal-oriented state compared with baseline state. The results showed that improvements in mood occurred only in the baseline group (Legrand and Thatcher, 2011).

3.3.4. *Studies that evaluate outdoor adventure programs, and education/ training/employment in green/blue environments*

A further set of studies (Table 4) employ a range of study designs to evaluate the mental health benefits of outdoor adventure opportunities. They indicate that wilderness excursions of 9–10 days lead to increased mindfulness and reduced stress (Mutz and Müller, 2016) and engender greater self-esteem through group belonging (Scarf et al., 2018). Studies evaluating longer (3–15 weeks) outdoor education programs also found measurable improvements in stress (Opper et al., 2014), self-esteem (McAnally et al., 2018) and social anxiety (Kardjono, 2017). Much shorter interventions also resulted in positive changes in the autonomy, competence, relatedness and enjoyment subscales of the Intrinsic Motivation Inventory (Mackenzie et al., 2018) and a reduction in anxiety (Kanters et al., 2002). Some of these evaluations included follow-up. Although benefits are not consistently sustained (Mackenzie et al., 2018), there were some longer-term effects on general mood (Opper et al., 2014) and depression symptoms (Kanters et al., 2002). A park-based prospective cohort study compared a violence prevention and mental health promotion after-school program with other after-school clubs, using youth crime rates as a proxy for violent behaviour (D'Agostino et al., 2020). They reported lower adjusted youth arrest rates three years post-intervention for the park-based programme. A comparison of mindfulness training in a botanical garden greenhouse with conventional (indoor) mindfulness training concluded that the green environment particularly helped beginner meditators to overcome problems with concentration and stress (Lymeus, 2019). Two studies also evaluated employment interventions in green or natural environments (Falxa-Raymond et al., 2013; Wolf and Housley, 2017). The first is a qualitative study of a group of young people who completed a training programme and then undertook 2–3 months' work experience in an entry-level "green job" (Falxa-Raymond et al., 2013). More than half of them described a positive change in their attitude towards themselves during this time. 94% of them cited gaining new knowledge and skills as a positive aspect. The second was a before-and-after study of a one-year conservation program. Quantitative findings suggested improvements in anxiety and social functioning. Qualitative themes included new skills and training, developing friendships, co-operation and the benefits of being outdoors in terms of health and happiness (Wolf and Housley, 2017).

In contrast to the studies of tightly controlled interventions delivered to homogeneous samples (Tables 1–3), these studies include more complex interventions, with multiple components potentially contributing towards outcomes. There is a common thread, of exposure to a green space or natural environment, but each intervention includes additional elements, comprising either education or training (50%) or outdoor adventure (50%). Some also involve reflection on these

Table 3
Main characteristics of studies evaluating physical activity programmes activity in a green/blue environment.

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/mechanisms	QA[b]
Flowers et al. (2018)	UK	60 undergraduate students. Mean age = 19.9 yrs.	Randomised controlled trial. Mixed methods.	Indoor vs Green: Indoor - stationary cycling 15 min in lab with view facing blank screen and grey wall; Green - stationary cycling on the edge of a large sports field consisting of flat grass-covered area interspersed with trees and hedge perimeter.	Profile for Mood States (POMS) – Shortened Version, Rosenberg's SelfEsteem Scale.	There was a marginally significant interaction effect of treatment x time on vigour ($p = 0.043$); the green-control group experienced a greater improvement in vigour (M = 2.00, 95% CI 1.06–2.94) than the indoor control group (M = 0.60, 95% CI -0.461.66). The interaction of time x treatment had no significant effect on self-esteem.		2
Kalak et al. (2012)	Switzerland	51 healthy high school pupils. Mean age 18.3; female 53%.	Randomised controlled trial. Experimental group (morning running) and control group (morning no exercise).	Vigorous physical exercise (planned and continuous cross country running, beginning on running track then into forest, for 30–37 min without interruption at a speed such that conversation is not possible) at 7am every school day morning for 3 weeks (total 15 sessions). Control group mustered at same place and time but did not run.	Perceived Stress Scale (PSS), coping with stress questionnaire, Curiosity and Exploration Inventory.	Mood in the morning significantly improved over time and was significantly higher in the running group (RG) than the control group (CG); the group × time interaction was also significant; mood in the morning increased significantly over time in the RG compared with the CG. Perceived stress, positive and negative coping strategies, and curiosity and exploratory behaviour did not differ significantly between groups or over time. Significant findings for somatosensory amplification ($p < 0.01$) and insomnia severity ($p < 0.001$) only.		4
Legrand and Thatcher (2011)	France	55 first year university students from a sport and physical education department in north eastern France. Mean age = 21.1 yrs. 62% male.	Students randomly allocated to conditions.	Walking outside on a track by the university campus for 15 min. In telic condition, individual feedback was given after the first lap of the track (600 m) on pace and it needing to be constant. In the para-telic condition no feedback was given on pace/ability.	Mood measured with the Tension Effort Stress Inventory (TESI), meta-motivational state measured using the Telic State Measure (TSM).	Following exercise, paratelic group had higher scores of pleasant mood states ($p < 0.01$). Post hoc analyses within each group - walking resulted in significant increase in pleasant mood states for the participants who were in the para-telic state, $p < 0.02$, but not for those who were in the telic state. Unpleasant mood states also revealed a significant group × time interaction ($p < 0.01$). The mean score for unpleasant mood states did not differ significantly between the two groups at initial assessment but significant after walking ($p = 0.03$).		2
Matsuura et al. (2011)	Japan	26 students with no disabilities. Males and females. Aged 19–25 yrs.	Controlled trial. No separate group for control.	Horse trekking for 30mins along route outside between fields/ forest/road/meadow vs 30mins on indoor riding simulator.	State-Trait Anxiety Inventory (STAI), POMS.	No significant interactions between exercise and time in 'tension-anxiety' and 'depression-dejection' subscales. There were effects of time. Depression-dejection scores were lower in horse trekking condition compared to riding simulator exercise. Anxiety-absent scores and anxiety-	Authors note that change of landscape, wind, and conversation with other riders are associated with horse trekking but not with using a riding simulator. Emotional wellbeing is also expected through interaction with a horse. Larger variations in physiological measures were found than in	4

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Table 3 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/mechanisms	QA[b]
						present scores were lower after horse trekking than after exercise with riding simulator ($p < 0.01$). Horse trekking had a greater psychological effect than the riding simulator exercise.	psychological measures, and these might be on the causal pathway e.g. changes in parasympathetic nervous activity.	
Nistbet and Zelensji, 2011, study 1	Canada	150 university students. 85 female, 56 male, 9 unspecified. Mean age = 20.8 yrs.	Randomised controlled trial.	Outdoor walking route along a canal vs an indoor walking route. Walk lasted ~17 min. Participants were also randomly assigned to be experiencers or forecasters of emotions.	Positive and Negative Affect Schedule (PANAS), Inclusion of Nature in Self (INS) scale.	ANOVA showed that experiencers and forecasters did not differ significantly in their ratings of positive affect but did differ in their ratings of negative affect: forecasters reported significantly less negative affect than experiencers, $F(1, 145) = 4.02$, $p = 0.05$. The interaction for negative affect was not significant. Participants failed to fully anticipate the hedonic benefits of contact with nearby nature. INS scores were higher for experiencers who walked outdoors ($M = 4.44$, $SD = 1.64$) than for experiencers who walked indoors ($M = 3.05$, $SD = 1.61$), $t(70) = 3.63$, $p < 0.01$, $d = 0.86$).	The studies showed that walking outdoors facilitated a sense of nature relatedness; the feeling of relatedness seems to have been mediated by the positive affect produced by walking in nearby nature. Feeling more related to nature can make you want to spend more time in nature.	2
Nistbet and Zelensji, 2011, study 2	Canada	80 university students	Randomised controlled trial.	As above, but walks were along different routes.	As above.	Participants who walked outdoors underestimated the substantial hedonic benefits of the walk, and participants who walked indoors overestimated their post-walk moods. Outdoor walks again produced greater state nature relatedness (INS score: $M = 4.18$ for outdoor participants and $M = 3.45$ for indoor participants), and this effect was again mediated by positive affect (Sobel $Z = 3.15$, $p < 0.01$; bootstrapping path = 0.62; 95% CI = [0.22, 1.18]).	As above.	2
Ozen (2015)	Turkey	30 university students. 17 male, 13 females.	Rock climbing was practised by participants for two months (two days in weekdays and 1 day at the weekend).	Recreational rock climbing either on artificial walls or real rock surfaces. The participants climbed in groups.	Anxiety measured using the Social Anxiety Scale for Adolescents (SAS-A).	Results suggest a significant improvement in social anxiety levels of students participating in the rock-climbing course. Across the three sub-scales (mean, SD): FNE pre-test = 25.96, 2.31; post-test = 24.06, 2.04 ($t = 4.59$, $p < 0.05$); S-SAD pre-test = 18.40, 3.63; post-test = 17.90, 1.88 ($t = 0.72$, n.s.); Y-SAD pre-test = 24.30, 2.89; post-test = 20.73, 2.18 ($t = 6.55$, $p < 0.05$); Total pre-test = 68.16, 6.81; post-	Social cohesion as rock climbing was completed in groups, and physical activity.	2

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Table 3 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/mechanisms	QA[b]
						test = 65.10, 4.45 (t = 3.44, p < 0.05). There were no significant differences between males and females in any sub-scales or total scores.		
Walter et al. (2013)	Germany	23 apprentices at Karlsruhe Institute of Technology, Germany; 52% female, stratification of gender (50% female in experimental, 55% control group); mean age 19.43 (±1.85) years.	Randomised controlled trial. Stratified for gender.	Aerobic endurance intervention conducted over 10 weeks during winter months. Participants in the intervention group participated in instructed outdoor running training twice a week. The control group participants were instructed not to alter their physical activity and exercise patterns during the control period; a continuous endurance method was applied to experimental group - initial duration of 30 min was continuously increased to 60 min over the 10 weeks, and intensity was progressively increased by adding short intervals of 2min above the individual training heart rate after week 6.	Mood.	Mood assessments: compliance with completing assessments reduced over time. Acute effects at T1 no significant effects. Acute effects across T1-T3 no significant effects. Medium term mood changes – no significant effects. For the mean values across the whole intervention period (T1–T3), energetic arousal, valence and calmness increased immediately after a training session (E: +10.4%; V: +17.8%; C: + 6.2%) but results were not significant (and arousal and calmness effect sizes were low). Valence findings were "marginally significant" at p = 0.07.		4

[a] References for measures are given in Supplementary Material.
[b] Quality assessment score out of 6. BAGE: Belief About Green Exercise questionnaire; INS, Inclusion of Nature in Self scale; PANAS: Positive and Negative Affect Scale; POMS, Profile of Mood States – Shortened Version; PSS: Perceived Stress Scale; SAS-A: Social Anxiety Scale for Adolescents; STAI: State-Trait Anxiety Inventory; TESI: Tension-Effort Stress Inventory; TSM: Telic State Measure.

Table 4
Main characteristics and results of studies evaluating outdoor adventure programmes, and education/training/employment in green/blue environments.

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
D'Agostino et al. (2020)	USA	The intervention was offered in areas with a population that was 48% male, 60% Hispanic, and 29% non-Hispanic black. In all, 33% of households were single parent and 33% were low income. The program served a mean (SD) of 501 (37) youths per year; total population 34,046.	Prospective cohort study.	Fit2Lead: a park-based violence prevention and mental health promotion afterschool programme.	Juvenile arrest rate (per 10,000 youths ages 12–17 years across all targeted zip codes), and change in arrest rates (all offenses) per year among youth ages 12–17 years across matched zip codes for 3 years before and after program implementation (2013–2018).	Adjusted Difference-in-Differences Poisson Regression Estimates of the Association of Program Implementation with Youth Arrest Rates Within 36 Zip Codes in Miami-Dade County, Florida. After programme implementation – incidence rate ratio (IRR) (95%CI) 0.84 (0.84–0.85) $p < 0.001$. Programme present – IRR (95%CI) 2.05 (1.65–2.56) $p < 0.001$ Program present × after program implementation – IRR (95%CI) 0.81 (0.76–0.85) $p < 0.001$.		2
Falxa-Raymond et al. (2013)	USA	12 males, 4 females, 16/20 were BAME, basic education status.	Qualitative.	Completing a training programme and then 2–3 month's work experience in an entry-level "green job".	Flexible open-ended questions through semi-structured interview, transcripts processed using NVivo software.	Thematic analysis revealed key themes; motivations, knowledge/skills, attitudes, significance of environmental work, and challenges faced. Motivations included: inspired by significant others both before (88%) and during work placement (69%), interest in environment (69%), being an "outdoor person", contributing to environmental benefits (19%), work pride. Attitudes included: Change in attitude toward self, positive (56%) or neutral (25%); toward work, 31% appreciated the freedom offered, 13% negative toward work; toward the environment – 81% had a positive outlook toward the environment following the job, and 56% had greater awareness of local environment.		7/9[c]
Kanters et al. (2002)	USA	Medical students from cohorts 1997 (n = 26), 1998 (n = 57), 1999 (n = 52).	Cohorts 1999 received the intervention. Cohorts in 1997 and 1998 were control groups.	Outdoor experiential training activities conducted at park close to campus during the year.	Profile for Mood States (POMS).	There were significant between-group differences for early semester anxiety-tension ($F = -16.75$, $p < 0.001$),	The activities were designed to create group cohesiveness and foster social support.	2

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Table 4 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
						early semester vigour activity ($F = 8.96$, $p < 0.01$), exam period depression- dejection (F- 4.99, $p < 0.05$), and exam period fatigue-inertia ($F = 6.09$, $p < 0.05$). Outdoor experiential training had a significant effect on several mood states. Measures of anxiety-tension, vigour activity, and depression-dejection mood states before the freshman semester were significantly lower for subjects in the intervention group than those reported for the control group.		
Kardjono, 2017	Indonesia	62 male and 16 female freshman students (analysed separately) from the Physical Education and Health Department at the Indonesian University of Education. Ages typically ranged from 18 to 20 years.	Controlled trial.	4-week Hiking Program, with a frequency of hiking 3 times in one week difficulty of the hiking was gradually increased subjects were encouraged to enjoy and learn about nature and to freely meditate.	The Liebowitz Social Anxiety Scale (LSAS).	For men, there was a reduction in anxiety in both groups, but it was stronger in the intervention group ($p < 0.05$). For women, there was a larger reduction in anxiety in the intervention group, but this was due to elevated levels before the intervention. There was no evidence of an effect ($p < 0.25$).	Suggested mediators are fresh air, natural scenery, 'active meditation'.	1
Lymeus (2019)	Sweden	Students ($n = 159$ recruited, but data used from 139). Participants experienced stress or concentration problems in their daily lives as students, and with no or little meditation experience.	Randomised controlled trial.	Restoration skills training (ReST) in a botanical garden greenhouse compared with traditional indoor mindfulness training.	Perceived Restorativeness Scale (PRS), Perceived Stress Scale (PSS), Swedish Core Affect Scale (SCAS) and the Toronto Mindfulness Scale (TMS).	No statistical data are reported. ReST is reported to help people with stress and concentration problems to meditate effortlessly and learn important restoration skills. ReST was also attended by generalized attentional performance improvements similar to those achieved with CMT. The ReST course confers sustained psychological health benefits with regard to dispositional mindfulness and self-perceived cognitive functioning. Regarding chronic stress, the benefits were less consistent and less sustained. The main finding is that the ReST approach to mindfulness training		2

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Table 4 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
						appears to support beginning meditators with concentration problems and stress better than conventional mindfulness training.		
Mackenzie et al., 2018	New Zealand	22 high school students. Mean age = 15.7 yrs. 59% male.	Within subjects. No control group.	5-day outdoor adventure-based science course at a residential school near a lake, state park and ski area.	Self-report intrinsic motivation and self-determination measured with the Short Flow State Scale (SFSS) and the Intrinsic Motivation Inventory.	The analysis of variance showed main effects for steps per day, flow, intrinsic motivation, autonomy, competence, relatedness, enjoyment, value and learning climate were significant ($p < 0.001$ - $p < 0.05$). Post-hoc comparisons indicated that steps per day, flow, intrinsic motivation, autonomy, competence, relatedness, enjoyment, and learning climate were all significantly higher in the OASC setting compared to both pre and post school settings.	The current results complement literature identifying psychological benefits of outdoor adventure, such as increased outdoor skill-based self-efficacy, autonomy, and positive academic attitudes and motivation.	3
McAnally et al. (2018)	New Zealand	104 boarding school students. Males only. Mean age = 14.43 yrs.	Cohort study. Students from 2 schools assessed during week 2 and 15 of school year.	Tihoi school – outdoor education programme where students do 3 days of outdoor activities (kayaking, rock climbing etc) per week as well as 4 days of normal school classes. St Pauls - main school with no outdoor programme.	Satisfaction with Life Scale, Rosenberg Self-Esteem Scale, Strengths and Difficulties Questionnaire (SDQ), Remote Associates Test, School achievement, Gratitude questionnaire.	Life satisfaction St Paul's boys did not show any change in scores over time whereas life satisfaction increased among the boys at Tihoi (fully adjusted model suggests improvements in life satisfaction, coef. 1.4 (−0.2, 3.0), $p = 0.091$). St Paul's boys did not show any change in their self-esteem scores over time whereas self-esteem increased among the boys at Tihoi (coef. 1.5 (0.2, 2.8), $p = 0.022$). The intervention was also associated with improvements in gratitude (coef. 2.2 (0.7, 3.7), $p = 0.005$). There was no evidence of a difference for any of the other outcomes.	Social cohesion and physical activity were important parts of the programme.	2
Mutz and Müller (2016), study 1	The Alps	12 pupils from a German high school (14yrs). 5 females, 7 males.	Pre-post design. No control group.	9-day hike across the Alps ~175 km. The hike focuses on values of self direction, initiative, leadership and	Perceived Stress Questionnaire (PSQ), General Self-efficacy Scale (GSES), Mindful Attention and Awareness Scale	Perceived stress partially decreased after intervention. The PSQ subscale on "worries" decreased (effect size = -0.47, $p = 0.069$). A	A major focus of the excursion was around social cohesion and leadership.	3

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Table 4 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
				personal responsibility.	(MAAS), subjective wellbeing (SWB).	moderate to large change is demonstrated for the PSQ subscale "demand", where participants report significantly lower values after the completion of the hike (effect size = -0.66, p = 0.022). Results also reveal a large increase in mindfulness (effect size = 1.32, p = 0.001) among participants. SWB was affected substantially by the excursion: The mean life satisfaction score increased significantly (effect size = 0.58, p = 0.034). The increase in happiness was also considerable but failed to reach significance by a narrow margin (effect size = 0.47, p = 0.064).		
Mutz and Müller (2016), study 2	Norway	Experimental group - 15 undergraduate students from a German university. Ages 19–25yrs. 8 male. Control group – 7 students.	Pre-post design. Experimental group and control group (did not participate in excursion).	Summer excursion 8 days exploring wilderness and being in nature. Hiking, climbing, fishing, swimming in lakes, camping etc.	As above.	Intervention was associated with moderate to large changes in almost all aspects of mental health measured. First, participants indicate reduced stress according to the PSQ subscales "worries" (effect size −0.53, p = 0.030) and "demand" (effect size = - 0.92, p = 0.002). Participants scored higher in mindfulness (effect size = 0.54, p = 0.027) and self-efficacy (effect size = 0.90, p = 0.002) after the intervention. Mean life satisfaction score increased significantly by 0.67 points (effect size = 0.68, p = 0.010). Participants reported a large gain in momentary happiness after the excursion (effect size = 1.48, p < 0.001).	As above	3
Opper et al. (2014)	South Africa	76 grade 10 students. Males only. Ages 15–16 yrs.	Pre-post design with follow-up. No control group.	'The Journey'- a 23-day outdoor adventure education programme. The students participate in different activities and reflect	The Bar-On Emotional Quotient Inventory (Bar-On EQ-I), The Bar-On Emotional Quotient Inventory Youth Version (Bar-On EQ-I; YV).	The results of the MANOVA univariate tests show that all EQ facets differed significantly over time (p < 0.05). The results indicate a significant difference		3

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Table 4 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
				on their participation. It facilitates the development of emotional intelligence.		in total EQ scores from pre- to post1 (medium effect size), and from pre- to post2 (medium effect size), which suggests that participation in the intervention results in an increase in emotional intelligence skills. Participation in the intervention results in a sustainable increase in overall emotional intelligence, but with regard to the sustainability of the subskills acquired, the effect on certain skills is more lasting (i.e. intrapersonal skills, adaptability and general mood) than on others (i.e. interpersonal skills and stress management).		
Scarf et al. (2018)	New Zealand	173 youth aged 15–19 yrs. Experimental n = 100, control = 73.	Control group did not go on the voyage. Outcomes measured on day 1 and final day of the voyage.	10-day voyage on a sailboat around New Zealand. Tasks and activities were completed during the trip.	Self-esteem using the Self- Description Questionnaire III (SDQ III), Life Effectiveness self-concept sub-scale, group belonging.	Voyage participants experienced an increase in self-esteem from Time 1 to Time 2, t (99) = 5.143, $p < 0.001$, while control participants did not, t (72) = 1.283, p = 0.204. Voyage participants (n = 97, M = 18.155, SD = 2.977) reported higher levels of group belonging than did control participants (n = 72, M = 14.486, SD = 3.548), F (1, 167) = 53.236, $p < 0.001$, $\eta 2p = 0.242$. Study 1 revealed that participants' sense of belonging to their Watch Group predicted increases in self-esteem following the 10-day voyage. Study 2 replicated this result and showed that the relationship between group belonging and self-esteem remained when controlling for self-efficacy and group esteem.	Group work and social cohesion were important aspects of the trip.	1
Wolf and Housley (2017)	USA	218 Washington Conservation Corps (WCC) members pre-test, 240 post-test. Ages 1834 yrs with the majority 22–24 yrs.	Cohort. No control group.	Everyday work settings in urban forests, wildlife habitats, parks. Work involved park improvements, ecological restoration and	PSS, health overview, personal effectiveness measured using The Review of Personal Effectiveness with Locus of Control (ROPELOC).	WCC participants reported less perceived stress compared to others in their national age cohort both before and after their service year. Paired	Employment, social cohesion and physical activity.	3

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Table 4 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
				biological monitoring.		sample t-tests indicated a significant decline in perceived stress during the conservation work period pre-test mean (SD) = 12.74 (7.05), post-test = 11.23 (4.76); t (214) = 2.759, p < 0.006 (norms for US citizens under 25 years presented at 14.54–18.64). There were significant differences between pre- and post-scores for social functioning (difference(d) = 0.324 (CI = −7.67 to −0.635); t (206) = 2.327; p = 0.021), energy/fatigue (d = 0.345 (CI = 0.973 to 7.88); d = 0.672 (CI = 4.41 to 11.59); t (215) = 2.526; p = 0.012) and bodily pain (t (215) = 4.930; p < 0.001). The only subscale for ROPELOC that is sig. diff. between pre- and post-test was cooperative teamwork (6.83(SD = 0.99, CI = 0.019–0.377) versus 6.63 (1.01); t (216) = 2.179; p < 0.030). Themes discovered: profession interests and satisfaction, communication and teamwork, sensory experiences, overcoming challenges and learning new skills, ecosystems knowledge, and life transformations.		

[a] References for measures are given in Supplementary Material.
[b] Quality assessment score out of 6.
[c] Quality assessment score out of 9 (the number of yes's for CASP qualitative quality assessment). Bar-On EQ-I: The Bar-On Emotional Quotient Inventory; Bar-On EQ-I-YV: The Bar-On Emotional Quotient Inventory Youth Version; GSES: General Self-efficacy Scale; LSAS: The Liebowitz Social Anxiety Scale Mindful Attention and Awareness Scale; NEP: The New Ecological Paradigm; PRS: Perceived Restorativeness Scale; PSQ: Perceived Stress Questionnaire; PSS: Perceived Stress Scale; POMS: Profile of Mood States; ROPELOC: The Review of Personal Effectiveness with Locus of Control assessment; SDQ: Strengths and Difficulties Questionnaire; SDQ: III Self-Description Questionnaire III; SCAS: Swedish Core Affect Scale; SFSS: Short Flow State Scale; TMS: Toronto Mindfulness Scale.

experiences (Opper et al., 2014; Mutz and Müller, 2016; Scarf et al., 2018), which could be another important element. Evaluations of such interventions have studied group dynamics but have less often included mental health and subjective wellbeing as outcomes (Mutz and Müller, 2016).

3.3.5. Studies of exposure to residential vegetation and blue spaces

Five observational studies (Table 5) consider the relationship between residential exposure to vegetation or blue spaces and a variety of outcomes. Exposure to vegetation is commonly measured using NDVI, 'an indicator of greenness based on land surface reflection of visible (red) and near-infrared parts of the spectrum' (Ekkel and de Vries, 2017).

Dzhambov (2018) provides a longitudinal analysis of NDVI and mental health, including symptoms of depression and anxiety, at one-year follow-up. The authors found a relationship between exposure to neighbourhood green/blue space and mental health, as measured by the 12-item General Health Questionnaire (Goldberg and Williams,

Table 5
Main characteristics and results of studies of exposure to residential vegetation and blue spaces.

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/ mechanisms	QA[b]
Bezold et al., 2018	United States	9385 participants ages 12–18 years in the 1999 wave of the Growing Up Today Study. 59% female, 93% non-Hispanic white. All were children of nurses.	Cross-sectional	Normalized difference vegetation index (NDVI) at 250 m and 1250 m from subject's residence. Presence of blue space within these buffer zones.	Depressive symptoms were measured using self-reported responses to the McKnight Risk Factor Survey	Adjusting for race/ ethnicity, paternal education, maternal history of depression, census region, census tract percent white, and estimated PM2.5 exposure, an inter-quartile range (IQR) increase in peak greenness in the 1250 m buffer around each participant's home was associated with 11% lower odds of high depressive symptoms in fully adjusted models (OR 0.89, 95% CI 0.79–0.99). Annual average NDVI in the 1250 m buffer was also associated with lower odds of depressive symptoms (OR per IQR increase 0.90, 95% CI 0.83, 0.99). Results for both peak and average NDVI at 250 m were slightly attenuated compared to the 1250 m results, but the direction of association was consistent. Presence of blue space in either 250 m or 1250 m was not statistically significantly associated with depressive symptoms. This was true when all types of water were considered simultaneously and when interior and coastal water bodies were considered separately. The results for coastal areas suggested a protective effect of living within 250 m of the coast, but the confidence intervals were very wide (OR 0.29, 95% CI 0.04,2.01).		3
Dzhambov (2018)	Bulgaria	109 medical university students aged 1835 yrs (mean = 21 yrs).	Cross-sectional survey with 1-year follow up.	NDVI, residential exposure to blue space.	General Health Questionnaire (GHQ-12) – Bulgarian translation.	NDVI and blue space had a stronger correlation with lower GHQ-12 scores (better mental health) at follow-up (−0.26, $p < 0.05$) compared with baseline (−0.14). 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. In the longitudinal analysis, higher NDVI significantly correlated	Residential noise, air pollution and annoyance from environmental pollution.	2

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Table 5 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/ mechanisms	QA[b]
						with lower GHQ-12, but none of the indirect effects were significant. Living close to blue space (<300 m) was associated with lower GHQ-12 in both the cross-sectional (−0.18) and longitudinal analyses (−0.22, $p < 0.05$), but physical activity and restorative quality mediated this association only in the cross-sectional analysis.		
Dzhambov et al., 2019	Bulgaria	581 undergraduate medical students. 529 included for analyses. Mean age = 21.74 yrs.	Cross-sectional survey.	NDVI and Tree Cover Density map 2015.	Generalized Anxiety Disorder 7-item (GAD7) scale and the Patient Health Questionnaire 9-item (PHQ-9), NDVI, Mindful Attention Awareness Scale (MAAS), Perceived Restorativeness Scale (PRS).	The models for anxiety and depression indicated that higher greenspace, both objective and perceived, was consistently associated with better mental health. The associations between NDVI and both anxiety and depression showed a pattern of increasing magnitude from smaller to larger buffers, while the opposite pattern held for relationship between tree cover and depression. More greenspace was consistently associated with reduced scores on the anxiety and depression scales. Restorative quality was related to lower rumination, higher resilience, and lower anxiety and depression. Higher restorative quality was associated with lower rumination and better mental health.	Perceived greenness, restorative quality of the neighbourhood, dispositional mindfulness, rumination, and resilience to stress.	2
Herrara et al., 2018	Germany	1632 16–18-year-olds followed to 20–23 years.	Cohort study.	NDVI	School-related, university-related or job-related self-reported chronic stress was assessed by the Trier Scale for Assessment of Chronic Stress using work discontent and work overload subscales as outcomes	Higher greenness (quartile 4 vs quartile 1) was associated with less work discontent (OR 0.89; 95% CI 0.80 to 0.99) and less work overload (OR 0.87; 95% CI 0.78 to 0.96). Prevalence of high levels of work discontent and work overload decreased by increasing level of greenness in a buffer of 500 m around the home. For work discontent, results suggest a linear, inverse dose-response pattern across quartiles while for work overload we observed a 'J-shape' association. For students, the OR for work overload was <1 for all quartiles compared with the first quartile of NDVI. For	Mediation analysis confirmed that physical activity is not a mediator.	2

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Table 5 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/modifiers/ mechanisms	QA[b]
						workers, no statistically significant difference for work overload and work discontent was seen by NDVI quartiles.		
Wang et al. (2019)	USA	Adults, teenagers and children in 81,102 households.	Secondary analysis of the California Health Interview Survey (cross-sectional).	NDVI	The Kessler 6 (K6) Scale.	Strong evidence for decreased odds of serious psychological distress with increased greenness surrounding residence in teens, even after adjusting for major socio-demographic factors and neighbourhood socio-economic status.		2

[a] References for measures are given in Supplementary Material.
[b] Quality assessment score out of 6; GAD-7: Generalized Anxiety Disorder 7-item scale; GHQ-12: General Health Questionnaire – Bulgarian translation; K6: The Kessler 6 Scale; MAAS: Mindful Attention Awareness Scale; NDVI: The Normalized Difference Vegetation Index; PRS: Perceived Restorativeness Scale.

1988). Herrara et al. (2018) also provide longitudinal evidence, which may offer an insight into mechanisms. They report that greater levels of residential greenness when participants were aged 16–18 years are associated with lower levels of work stress when they reach age 20–23 years. This suggests a protective effect when transitioning to university or working life. In cross-sectional analyses the association between NDVI and mental health appears to be mediated by physical activity and restoration, though this does not hold in longitudinal analyses (Dzhambov, 2018). A later cross-sectional study found that NDVI was negatively associated with both anxiety and depression symptoms. The following variables were reported as mediators – perceived greenness, the restorative quality of the neighbourhood, dispositional mindfulness, rumination and resilience to stress (Dzhambov et al., 2019). Another cross-sectional study reported a negative association between NDVI and serious psychological distress. The outcome measure was the Kessler 6 scale (Kessler et al., 2003), which measures symptoms of anxiety and depression. The authors found that the relationship was mediated by pollution and social cohesion (Wang et al., 2019). A final cross-sectional study provides further evidence that NDVI is associated with reduced symptoms of depression but an association was not found for presence of blue space (Bezold et al., 2018).

3.3.6. *Studies of young people's perceptions of green spaces*

Another group of studies provided insight into how green spaces are perceived by young people, and how this could mediate the relationship between green space and mental health (Table 6). An experimental study compared perceptions of bamboo forests with those of an urban environment (Zeng et al., 2020). The forest was rated as providing a better environmental experience in terms of sensory perception, atmosphere, climate, space and place. An observational study compared different views in Tokyo (Asgarzadeh et al., 2014). More trees in the view increased spaciousness and monotony. Oppressiveness was reduced in views with more trees and more sky and increased in views with more buildings. Finally, increasing distance to trees reduced perceived oppressiveness and danger. This would suggest that the optimal environment in one in which trees and sky dominate rather than buildings, but with some distance to the trees. An experimental study by Wilson et al. (2016) found that walking in an urban park is perceived as being more restorative than walking on a busy street near traffic. It also reported that perceived noise mediates perceived restoration. Yang et al. (2011) showed that plants cause 'psychological noise reduction'. In other words, a green environment reduces perceived noise levels. Alizadeh et al. (2018) examined personal preferences for different green (forests, agricultural) and natural (mountains) landscapes and predictors of these. They found that personality type and the subject studied are associated with preference, suggesting that it is important to consider personal preferences if the impacts of green spaces are reliant on their use. Taken together, this set of studies suggest that greener environments are preferred, and are associated with restoration, partly by reducing perceived noise levels.

3.4. *The conceptual framework*

Based on the literature reviewed, we built on the existing literature to provide a conceptual framework that links particular elements of exposure to green spaces to the psychological outcomes of anxiety disorders and depression (Fig. 3). The model includes evidence about the modifying effects of young people's perceptions of exposure to vegetation and trees, mechanisms including the behaviours facilitated by green spaces (e.g. physical activity) and environmental exposures (e.g. noise and air pollution). We suggest tentative psychological mechanisms to explain how the restorative qualities of green spaces might lead to increased mindfulness and interrupted rumination (Bratman et al., 2015). Our model also suggest that a reduction in negative stimulation could enable restoration and possibly a reduction in the risk of anxiety disorder and depression. The framework demonstrates that there is experimental evidence linking elements of exposure to green spaces to mechanisms related to reduced environmental exposure to noise and air pollution, and transitory psychological states such as mood and relaxation. It also highlights a lack of evidence linking these to the outcomes of anxiety disorder or depression. Observational studies and evaluations of interventions provide some evidence of links between other potential mechanisms (e.g. improved social cohesion and resilience) and these outcomes.

3.5. *Analysis by subgroup*

Few studies compared results for males and females, despite clear differences in the epidemiology of mental health disorders in adulthood which emerge during adolescence. One exception, Kardjono (2017), suggests that a 4-week hiking programme reduced social anxiety for males, but induced pre-intervention anxiety for females. In an evaluation of a climbing programme, Ozen (2015) found that a climbing intervention reduced social anxiety overall, with no differences between men and women. Of the thirteen experimental studies described in Table 1, eight included only males. The one study that included only females reported similar results, suggesting that exposure to forests or parks have similar effects for males and females (Song et al., 2019). In terms of age groups, most of the experimental studies (Tables 1–3) were carried out with student samples of very similar ages. This means that

Table 6
Main characteristics and results of studies of young people's perceptions of green spaces.

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
Alizadeh et al. (2018)	Iran	384 volunteer high school students (192 girls, 192 boys). Mean age = 16.3 yrs. Range = 15–18 yrs.	Cross-sectional survey.	15 scenes of mountains, forest, and agricultural landscapes were shown to participants in random order.	Preferences were recorded using a 7point Likert scale, Cattell Sixteen Personality Factor Questionnaire (16 PF).	There were some associations between both personality type and subjects studied and preferences for environments, but the percentage of variance explained by these variables was low.		2
Asgarzadeh et al. (2014)	Japan	20 architecture and design students and graduates. 50% females.	Repeated measures observational survey.	15 scenes (3 evaluation locations for 5 building compounds) on a Tokyo street.	Perceptions of oppressiveness, and spaciousness, dangerousness, and pleasantness, monotony, beauty, strength, heaviness and fuzziness. Each question used a semantic differential rating system from 1 to 7.	Significant associations between distance variables (distance to trees and distance to buildings) with perceptions of oppressiveness and danger. Being farther from trees lowered oppressiveness (−0.25; $p < 0.01$) and dangerousness (−0.15; $p < 0.05$). The second model included tree-related variables (solid angle of trees, increased distance from trees), and building's solid angle as independent variables: with a greater solid angle view of trees, spaciousness increased (0.43; $p < 0.01$), monotony (−0.45; $p < 0.01$) and fuzziness (ambiguity) decreased (−0.54; $p < 0.01$). The third model included ground surface, trees, sky, and total building's solid angles as independent variables, and suggested that trees (−1.13; $p < 0.01$) and view of sky (−0.43; $p < 0.01$) can decrease oppressiveness. Oppressiveness (−0.33; $p < 0.05$) and perceived spaciousness of the environment (−0.45; $p < 0.05$) also decreased significantly with dominant views of ground surface. Oppressiveness increased significantly when the solid angle of the visible buildings increased but with the presence of trees, the building's oppressiveness was reduced.		2
Wilson et al. (2016)	USA	112 undergraduate students in a general education class.	Within-person randomised trial.	One-mile (approx. 20mins) paved walking trail through an urban park (compared with sidewalk next to busy highway).	Short-version Revised Restoration Scale (SRRS).	Higher levels of perceived restoration in the natural environment ($p < 0.05$).	Higher levels of perceived noise and danger in the street environment ($p < 0.05$). Perceived noise was a strong predictor of perceived	4

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Table 6 (*continued*)

Author	Location	Sample	Type of study	Exposure	Outcome measures[a]	Results	Mediators/ modifiers/ mechanisms	QA[b]
							restoration, but perceived danger was not an independent predictor.	
Yang et al. (2011)	China	40 randomly selected participants from a forestry university. 20 male, 20 female. Mean age = 23 yrs.	Non-randomised experiment.	Participants were exposed to simulated noises and videos of noisy street scenes and adjacent green spaces via video glasses.	Subjective emotional evaluation questionnaire completed after each scene.	90% of the subjects believed that landscape plants could contribute to noise reduction. Participants believed that hedges are the most effective barrier (80%), and overestimated the sound reduction effect of hedges. Landscape plants provide excess noise attenuating effects through subjects' emotional processing - "psychological noise reduction".	There was a highly significant asymmetry between the EEG activity of the vegetation scene and traffic scene groups.	0

[a] References for measures are given in Supplementary Material.
[b] Quality assessment score out of 6; 16 PF: Cattell Sixteen Personality Factor Questionnaire; SRSS: Short-version Revised Restoration Scale.

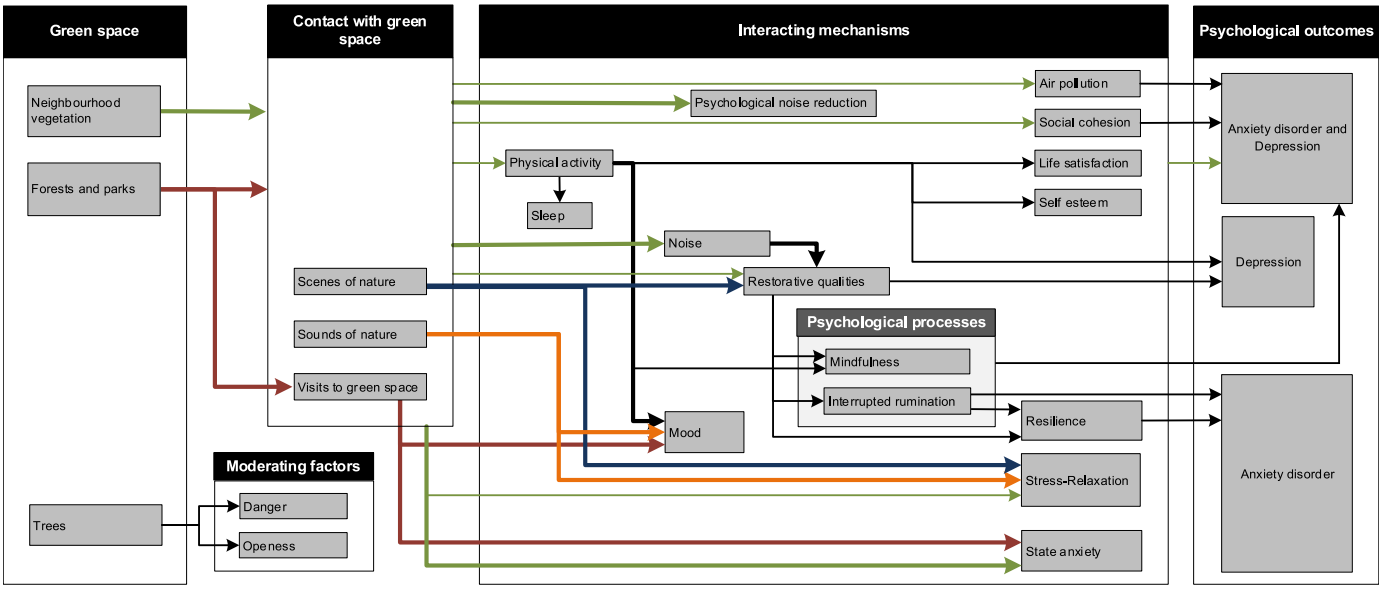

Fig. 3. Conceptual framework based on the literature in the review (Thicker lines represent evidence from experimental studies and thinner lines represent evidence from nonrandomised evaluations and observational studies. Colour coding differentiates pathways from each feature of green space). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

results cannot be compared by age. Educational or adventure programmes were positively evaluated for both school-age teenagers and students (Table 4). There is evidence that neighbourhood green space is less strongly linked to depression for high school students than middle school (Bezold et al., 2018). There was no evidence of effect modification by sex.

Few studies in this review considered ethnicity as a moderator. While 61% of the experimental studies (Tables 1–3) were carried out in Asia, the predominantly observational studies (Tables 4–6) have a global spread. Included studies did not consider effectiveness in different socioeconomic groups. Many of the experimental studies used students as participants, who are unlikely to represent all socioeconomic groups. Two US studies reported ethnic and sociodemographic diversity within their sample, but neither of these studies report results for different groups (Falxa-Raymond et al., 2013; D'Agostino et al., 2020).

It is notable that much of the experimental research considered in this review focuses on forests as the exposure or intervention. Some studies reported elevated state-anxiety immediately prior to a walk in a forest, which suggests that this can be an unfamiliar or even threatening environment.

One study found some evidence that young people's preferences for mountains, forest and agricultural landscapes is linked to personality type (Alizadeh et al., 2018). We also found some evidence that the impacts of exposure to green spaces and outdoor exercise might be moderated by personality type (Song et al., 2018) or by psychological state (Legrand and Thatcher, 2011). For example, those with high-trait anxiety levels experienced a greater reduction in feeling of "depression–dejection" after walking through forest areas than those with normal and low-trait anxiety levels (Song et al., 2018). Differences in goal-orientation explain why individuals do not all respond in the same

way to exercise (Legrand and Thatcher, 2011).

4. Summary

There is good evidence that a 15-min walk in a forest or park can improve mood and state anxiety compared to an urban environment (Song et al., 2018, 2019). It is not clear, however, whether this corresponds to a reduced risk of developing anxiety or depression. The impacts of different components of nature can be broken down, and such studies provide evidence of the restorative qualities of viewing or listening to nature, with associated improvements in mood and relaxation (Benfield et al., 2014; Tedja and Tsaih, 2015; Chang et al., 2008; Chan KLE, 2015). There is less good evidence about the social and psychological processes, such as activation or rumination, resulting from the opportunities for physical activity and restoration afforded by green space, or how these link to psychological disorders. There is limited evidence about how young people perceive green spaces, and how this affects their use of green space. There is also limited evidence of poor quality about the effects of exposure to blue spaces for young people's mental health.

5. Discussion

We synthesised a wide range of evidence about the role of access to green space in preventing anxiety and depression amongst 14–24 year olds, and developed a tentative conceptual framework linking exposures to outcomes, via a number of mechanisms including psychological processes. We found evidence that exposure to forest environments leads to greater momentary mental wellbeing compared to being on an urban street, and that urban parks can deliver similar benefits to forests. These studies did not provide evidence about longer-term outcomes such as symptoms or diagnoses of anxiety or depression. However, the evidence from observational studies that residential exposure to vegetation is associated with reduced risk of depressive symptoms for young people is crucial in terms of implementing change that will have broad reach and lasting benefits (Vanaken and Danckaerts, 2018). Observational studies also provide some insights into causal mechanisms, such as links between green space and restorative properties leading to reduced rumination (Dzhambov, 2018; Dzhambov et al., 2019). While adolescents spend more of their time further from home than children, young people are less likely to own cars or have access to private gardens. Neighbourhood green space and vegetation is therefore crucial to their well-being (as recognised in the Sustainable Development Goals; UN Environment Programme, 2020).

The importance of green space is partly because it enables many other activities that benefit mental health. Hartig et al. (2014) and then Nieuwenhuijsen et al. (2017) suggest four mechanisms through which exposure to natural environments may affect mental health. These are environmental exposure/air quality, physical activity, social contacts and cohesion, and restoration and stress reduction. Less researched mechanisms include microbial exposure and biogenic volatile organic compounds. It is hard to disentangle the impacts of green space and such mediators, and the psychological processes by which green space may reduce the risk of anxiety or depression are unclear. Many of the included studies cite Attention Restoration Theory (Kaplan and Kaplan, 1989; Ohly et al., 2016). This theory suggests green space engages indirect attention and thus provides rest for directed attentional capacity, and therefore presumably interrupts unhelpful rumination or worry. The papers reviewed suggest that green spaces promote mindfulness, mediated by physical activity and restorative qualities. We hypothesize that this in turn reduces rumination (Short et al., 2020) and improves psychological outcomes. Others have suggested that greenspace reduces the tendency to ruminate and thereby increases adaptive coping through enhanced psychological resilience (Marselle et al., 2019). Similar benefits might be afforded by the practice of mindfulness (Chi et al., 2018), but this requires training and effort. It seems that green environments encourage 'effortless mindfulness'. This is supported by one study that found a green setting when learning mindfulness was particularly helpful for beginners (Lymeus, 2019). An evaluation of a hiking programme encouraged participants to reflect on the natural surroundings and engage in 'active mindfulness'. It has been found that regular mindfulness can promote trait mindfulness (Quaglia et al., 2016). This provides a possible mechanism to a sustained reduction in the risk of psychological disorders.

5.1. Recommendations for research

In order to understand if exposure to green space prevents anxiety and depression amongst people aged 14–24 years, it is essential that more studies examine longer-term follow-up. Further research must explore the type and frequency of exposure associated with longer-lasting impacts indicative of prevention of anxiety and/or depression. Another recommendation for future research is to measure changes in psychological processes such as rumination and activation that are key to anxiety and depression. Such research should utilise psychological theory to underpin explorations of the impact of green space on mental health.

The studies used a wide variation of interventions/exposures, considering different types of green space, different durations and varying activities. To allow an improved dialogue with mental health science, these interventions could adopt a more structured way of reporting the contents of the exposure, similar to those laid out in the TIDieR guidelines (Hoffmann et al., 2014). Systematic reporting would then allow investigations into impacts of green space on mental health to be more readily evaluated, replicated and potentially implemented.

Although it was included in our search terms, we found few studies about the benefits of blue spaces for young people's mental health, and these studies tended to be of poorer quality. This reflects the finding of our earlier scoping review (Reece et al., 2021), in which only 2% of sources related to blue spaces. However, this is a rapidly growing area of research. In terms of potential mechanisms, more work is needed on the importance of microbial exposure. Future studies should also consider the role of demographic variables, previous experiences (e.g. with outdoor activities) and individual preferences (for different environments).

5.2. Recommendations for practice

Recommendations for practice should be interpreted with some caution, as there is limited evidence of mixed quality regarding prevention. Recommendations might include consideration of social prescribing of adventure interventions for young people at risk of anxiety and depression and, at a population level, the integration of outdoor adventure opportunities into educational curricula. Evaluations of such interventions provide some limited evidence of sustained effects on general mood and feelings of depression (Opper et al., 2014; Kanters et al., 2002). However, there is as yet no clear evidence about the type, length or frequency required to have a lasting impact, which may be a barrier to prescribing. . High-quality longitudinal studies are still needed to estimate the long-term effects of regular exposure to green space on clinical measures of anxiety and depression. However, based on the studies we reviewed and the insights of our panel, we conclude that access to green space is likely to enhance other interventions to improve mental health, such as physical activity (Nistbet and Zelensji, 2011; Matsuura et al., 2011), mindfulness practice (Lymeus, 2019) and problem-solving. It also has multiple additional benefits (Hunter et al., 2019) in terms of health and wellbeing for the rest of the urban population, improving thermal comfort and biodiversity in cities, and reducing pollution and risk of flooding. These all have implications for the future health of today's young people.

5.3. Limitations

We have taken a novel approach to reviewing the evidence about exposure to green spaces and mental health for young people, drawing on a wider range of literature than previous reviews. While this approach has helped bridge a gap (from immediate psychological responses to changes in clinically measurable depression or anxiety disorders), we acknowledge several limitations. First, the search terms and databases we used may have missed relevant papers. Second, screening was carried out by one researcher. Third, though we set out to include all study designs, the review is heavily weighted towards quantitative research. This is partly due to the limited qualitative research on this topic with young people, but also partly due to the additional exclusion criteria at the full text screening stage, which sought to select the most relevant sources from a large number of eligible studies. Nevertheless, it is worth noting that many of the included studies applied quantitative approaches to qualitative descriptions of attitudes or feelings, and some used mixed methods. Fourthly, thirteen of the studies (27%) include a proportion (<50%) of participants outside of the target age range (14–24 years). Due to the heterogeneous nature of the included studies, we did not formally assess publication bias. Although publication bias is a possibility, we did include a search of grey literature which did not reveal unpublished non-significant findings. We must also acknowledge that the studies were of varying quality and that selective reporting within studies may have biased our findings.

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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.

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Appendix A. Supplementary data

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