Nature exposure and mental health during the COVID-19 pandemic: A Navigation Guide systematic review with meta-analysis

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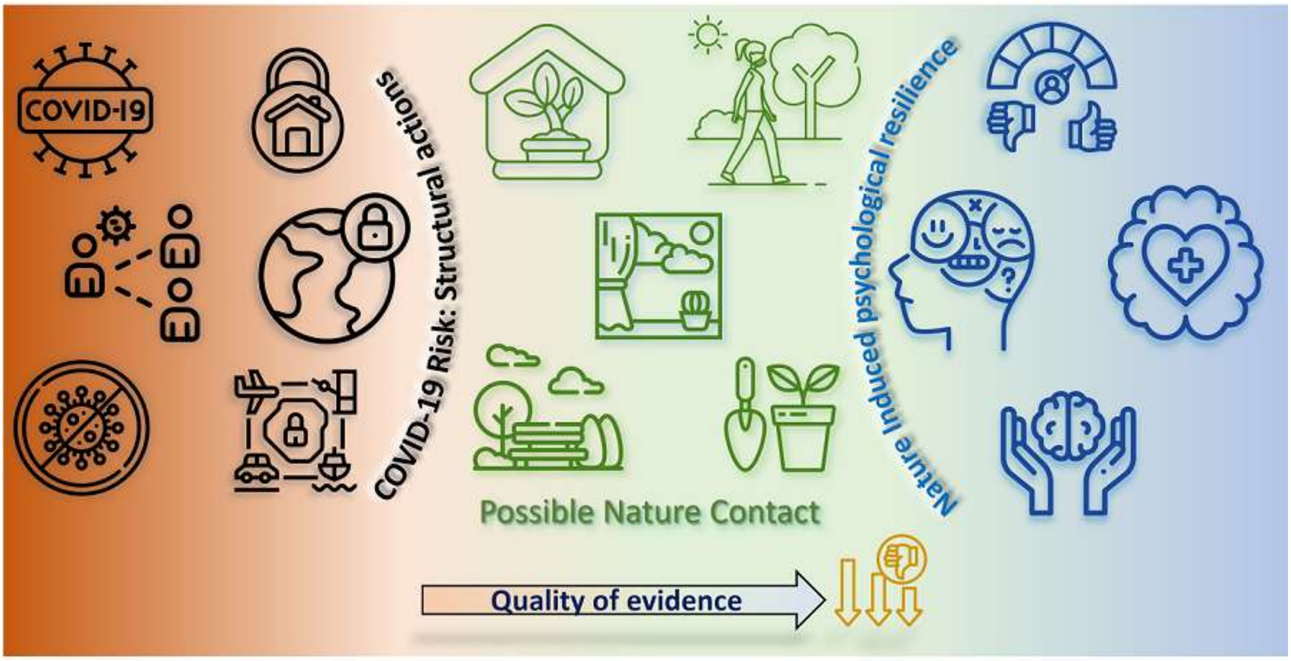
Highlights

- Nature contact may protect mental health during public health crises.
- Many nature-mental health pairings were studied during the pandemic.
- Access to gardens reduced the risk of depression and anxiety.
- Visiting green spaces potentially protected against poor mental health.
- Quality of evidence was very low for all mental health outcomes.

Graphical Abstract



Abstract

Previous reviews concluded that nature contact was an important coping strategy against poor mental health during the COVID-19 pandemic. However, the quality of evidence in these reviews was not sufficiently documented in terms of the risk of bias in reviewed studies. We attempted to fill this gap with a Navigation Guide systematic review and meta-analyses on the associations between nature exposure and mental health during the pandemic. Searches in PubMed, Web of Science, Scopus, CINAHL, and PsycInfo retrieved relevant articles published between January 1, 2020, and April 30, 2022. Included studies reported observational findings from human participants with indoor or outdoor nature exposure and measures of mental health. We used the Navigation Guide methodology to assess the risk of bias and quality of evidence across the body of evidence for each mental health outcome. A total of 4,464 articles were initially identified. After the screening, 59 were ultimately included. Studies reported diverse variables of nature availability, green space visit frequency, green space accessibility, and green space type (e.g., indoor vs. outdoor) with 12 mental health outcomes. Meta-analyses found access to gardens was associated with lower odds of depression (OR=0.71, 95% CI=0.61-0.82, I^2=0%, n=3) and anxiety (OR=0.73, 95% CI=0.63-0.84, I^2=0%, n=2). Higher frequency of visits to greenspace during the COVID-19 pandemic was associated with improved mental well-being (OR=0.10, 95% CI=0.07-0.14, I^2=0%, n=2) and general mental health (OR=0.11, 95% CI=0.03-0.38, I^2=82%, n=2). The quality of evidence was "very low" for all outcomes, and high levels of bias and between-study heterogeneity were observed in the studies of nature exposure and mental health (41% of studies had high, 24% probably high, and 35% had a low risk of bias). Nonetheless, given trends observed in the results, nature-based infrastructure that emphasizes exposure to nearby nature may have promoted psychological resilience during this public health crisis.

Keywords: Nature exposure; Mental health; Greenspace; COVID-19; Navigation Guide; Meta-analysis

1. Introduction

Many studies have documented the negative impacts of the COVID-19 pandemic on mental health (Banerjee, 2020; Patwary et al., 2022; Rossi et al., 2020; Talevi et al., 2020). Symptoms of depression, anxiety, and psychological disorder became more prevalent due to COVID-19-related structural actions such as lockdowns (Chatterjee et al., 2020). High rates of post-traumatic stress disorder (96.2%), anxiety symptoms (44.6%), insomnia (34.0%), and distress (71.5%) were also reported (Vindegaard & Benros, 2020). Stressors such as prolonged quarantine, fear of infection, frustration, and boredom were linked to long-lasting posttraumatic stress symptoms, confusion, and anger throughout the pandemic (Hossain, Tasnim, et al., 2020). An umbrella review of mental health during the early stages of the pandemic observed that anxiety, depression, sleeping disorder, posttraumatic stress symptoms, low self-esteem, and a lack of self-control were especially prevalent among those who were subjected to physical isolation (Hossain, Sultana, et al., 2020). Even suicidal behavior increased due to mental distress over radical shifts in life and economic downturns. For example, in the year before the pandemic, the number of Canadian suicides linked to unemployment was expected to rise from 418 to 2114 (Xiong et al., 2020).

Before the pandemic, numerous studies indicated the potential benefits of residential green space on psychological wellbeing (Boers et al., 2018; Bos et al., 2016; Gascon et al., 2018). The mental health-promoting benefits of nature were attributed to nature exposure promoting healthy behaviors such as physical activity and social interaction while also providing relief from stress and attentional fatigue (Bratman et al., 2019; Markevych et al., 2017). Three narrative syntheses (Heckert & Bristowe, 2021; Labib et al., 2022; Lanza-León et al., 2021) have concluded that nature exposure was linked to better mental health during the COVID-19 pandemic. Although the majority of these studies indicated positive circumstantial evidence of nature exposure benefits during COVID-19, no risk of bias or quality evaluation was provided to assess this evidence critically. We determined that it is essential to have a systematic review that is up-to-date, accurate, and clear to make informed decisions about urban planning and environmental interventions (Luque-García et al., 2022). To achieve this goal, we adopted the Navigation Guide systematic review methodology that was first introduced in 2011 to unite the clinical sciences and environmental health. Its rigorous, straightforward, and transparent methodology makes it ideal for supporting policy decisions and other forms of implementation (Woodruff & Sutton, 2014), which is in line with the objectives of this review. Therefore, we conducted a Navigation Guide systematic review with meta-analysis to evaluate the quality and strength of evidence for associations between nature exposure and mental health during the COVID-19 pandemic.

2. Methods

We conducted the systematic review according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021), Navigation Guide framework (Woodruff & Sutton, 2014), and the Cochrane Collaboration and Grading of Recommendations Assessment Development and Evaluation (Guyatt et al., 2008). The review protocol was preregistered on PROSPERO (ID: CRD42021276223, available from: https://www.crd.york.ac.uk/prospero/).

2.1. Eligibility criteria

Included studies met the following “Population”, “Exposure”, “Comparator”, “Outcome”, and “Study design” (PECOS) criteria:

- **Population:** Human participants with no restrictions on age, sex, and specific area; studies with non-human subjects were excluded.
- **Exposure:** Exposure to indoor and outdoor nature, which included blue and green space, natural outdoor space, indoor greenery, vegetation index, window views of outdoor natural landscapes, gardens, parks, forests, and tree canopy; simulated exposures (i.e., virtual reality) to nature were excluded.
- **Comparator:** Group without exposure or less exposure to nature served as a comparison or control group.
- **Outcome:** Prevalence, incidence, or continuously measured level of a mental health construct, including anxiety, depression, stress, general mental health, mood state, positive and negative affect, loneliness, emotional distress, wellbeing, and happiness during the COVID-19 pandemic; physical health outcomes were excluded.
- **Study design:** Cross-sectional, case-control, and cohort studies were included; experimental studies were excluded.

We further restricted the eligible articles to those that were peer-reviewed, published since January 1, 2020, which corresponded to approximately the start date of the global pandemic (Zhu et al., 2020), and provided full-texts in English. Additional exclusion criteria were articles on other respiratory viruses (influenza, SARS, MERS), articles not describing original research (i.e., reviews, editorials, commentaries), unpublished data, grey literature, and conference proceedings.

2.2. Search strategy

Five databases were used in the keyword search: PubMed, Web of Science, Scopus, CINAHL, and PsychInfo (**Supplementary Material S1**). Search terms related to nature exposure (e.g., greenness, blue space, and natural environment), mental health (e.g., wellbeing, mental health, and stress), and coronavirus (i.e., COVID-19 and pandemic) were considered for article searches. We also reviewed the reference lists of the articles found in the database searches and the author's personal reference libraries to ensure the inclusion of all relevant records. The search was last updated on April 30, 2022.

2.3. Study selection

Potentially relevant citations were imported into Rayyan (https://www.rayyan.ai/, accessed on April 30, 2022). Six reviewers (MMP, MB, MZH, ASD, MFT, MAR) carried out title-abstract screening independently after removing duplicates. Subsequently, six authors independently reviewed the full texts for inclusion. In cases where recommendations varied between reviewers, decisions were determined through consensus.

2.4. Data extraction

Data extraction and cross-checking were independently carried out by six authors (MMP, MB, MZH, ASD, MFT, MAR). Data considered study characteristics (author, publication year, study period, study design, sampling, and data collection method), population characteristics (such as location, sample size, age, and gender), nature exposure assessment (e.g., access to the park, gardening, window viewing of nature, indoor plant), mental health outcomes (e.g., anxiety, depression, stress, life satisfaction), statistical analysis, main findings including adjusted estimates with corresponding 95% confidence intervals (CI) and descriptive results, and mediator and confounders in adjusted models. We contacted the corresponding author of each included article that did not report these data to complete data extraction (**Supplementary Material Table S1**. Three authors (MMP, MB, and ASD) resolved discrepancies in the extracted data through consensus.

2.5. Risk of bias

The Navigation Guide methodology is a specific approach developed for conducting systematic reviews in the field of environmental health. This methodology has been designed to provide a robust and transparent method for synthesizing and evaluating the existing evidence in this field. By using this methodology, we assessed the quality and strength of the evidence of our systematic review (Woodruff & Sutton, 2014). Specific risks of bias spanned the following domains: recruitment, blinding, exposure assessment, confounding, incomplete outcome data, selective reporting, conflict of interest, and other biases following previous literature (Luque-García et al., 2022). The rating system for each domain was "low", "probably low", "probably high," or "high" risk of bias. "Not applicable" was also considered for select domains (**Supplementary Material S2**). Judgments were assessed by three reviewers (MMP, MB, and ASD). In cases of disagreement, a fourth reviewer (AMD) would assist with reaching a consensus. If the majority of the domains were rated "low" or "probably low", the overall rating was "low" or "probably low." Similar judgments were made for "high" or "probably high" ratings.

2.6. Quality of evidence

The Navigation Guide integrates the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) approach and classifies the overall body of evidence quality into four categories: "high," "moderate," "low," and "very low." In accordance with the Navigation Guide methodology, the initial rating for the quality of evidence is set at "moderate" for observational studies and then evaluated based on the criteria established by GRADE. Using this methodology, we determined the collective quality of evidence across studies for each outcome (Woodruff & Sutton, 2014).

The GRADE approach combines downgrades and upgrades of this default rating. Five factors could downgrade the quality level of the body of evidence: risk of bias, indirectness, inconsistency, imprecision, and publication bias. Depending on the severity of suspected bias, the quality of evidence was downgraded by one level for a rating of "serious concerns" and by two levels for a rating of "very serious concerns." Three factors could upgrade the quality level: large magnitude of effect, dose-response, and confounding minimizes effect (Johnson et al., 2014).

Evidence of inconsistency included effect size heterogeneity and non-overlapping of the confidence interval ranges across studies (Guyatt, Oxman, Kunz, Woodcock, Brozek, Helfand, Alonso-Coello, Glasziou, et al., 2011). Indicators of imprecision were a limited number of studies (<3 studies), wide confidence intervals, small sample sizes, or studies showing opposing associations for the same exposure-outcomes pair (as a measure of a broad 95% confidence interval)(Guyatt, Oxman, Kunz, Brozek, Alonso-Coello, Rind, Devereaux, Montori, et al., 2011). As a measure of indirectness, the harmony of the studies' populations, exposures, and outcomes to the focused populations of this review were examined (Guyatt, Oxman, Kunz, Woodcock, Brozek, Helfand, Alonso-Coello, Falck-Ytter, et al., 2011). A high probability of publication bias would be indicated by the presence of funnel plot asymmetry, gauged visually and/or statistically. However, in the end, efforts to assess publication bias were undermined by the small number of study records for most of the exposure-outcome pairs ($n < 5$).

According to the GRADE instructions, consideration was given to upgrading based on a large magnitude effect size, the finding of a dose-response trend, and a low probability of residual confounding. The criteria for "large"/"very large" magnitude of effect in the original GRADE guidelines (Guyatt, Oxman, Sultan, Glasziou, Akl, Alonso-Coello, Atkins, Kunz, et al., 2011) are not applicable to environmental health research. Probable downgrades or upgrades were: 0 (no change from initial quality rating), −1 (1 level downgrade) or – 2 (2 level downgrade), +1 (1 level upgrade) or + 2 (2 level upgrade) (Balshem et al., 2011). Two reviewers (MMP and MB) independently rated the evidence and then compared their ratings to establish a conclusion. Disagreements were settled through discussion. All the assessment instructions with rationale for judgments were provided as **Supplementary Material S3**.

2.7. Meta-analyses

We conducted meta-analyses for exposure-outcome pairs with at least two studies. Narrative descriptions were provided for findings with more limited studies. We did not combine in the same model effect estimates from studies of different designs, nor did we pool together incomparable effect estimates or multiple estimates associated with statistical tests that shared subjects. For studies reporting more than one independent effect estimate for the same exposure-outcome pair, we planned to extract the estimate that provided more direct evidence or was less biased. We combined effect sizes for adults and youth. Given valid concerns that the commonly applied random-effects estimator can produce overly liberal results, we used the inverse-variance heterogeneity model implemented in MetaXL v 5.3 (EpiGear International Pty Ltd, Sunrise Beach, Queensland, Australia). Simulation research has confirmed that this estimator provides a more conservative pooled effect size and associated 95% CI (Doi et al., 2017). Criteria for statistical heterogeneity in the models were a significant Cochran's Q at the $p < 0.1$ level and the value of the I^2 statistic as follows (mild, < 30%, moderate, 30–50%, or high, > 50%) (Higgins & Thompson, 2002). Judgments on publication bias for each exposure-outcome pair were based on visual inspection of funnel plot asymmetry and Egger's regression test in cases of at least 10 studies (Egger et al., 1997), and Doi plot asymmetry and the Luis Furuya-Kanamori (LFK) index of >|2| in cases of at least 5 studies for an exposure-outcome pair (Furuya-Kanamori et al., 2018).

3. Results

3.1. Characteristics of included studies

We identified 4,464 articles in preliminary searches (**Figure 1**). Of these, 2,749 (61.6%) were duplicates. After assessing eligibility based on the title and abstract, 128 articles were eligible for full-text screening. Eventually, 59 articles were included in the review (**Table 1**).

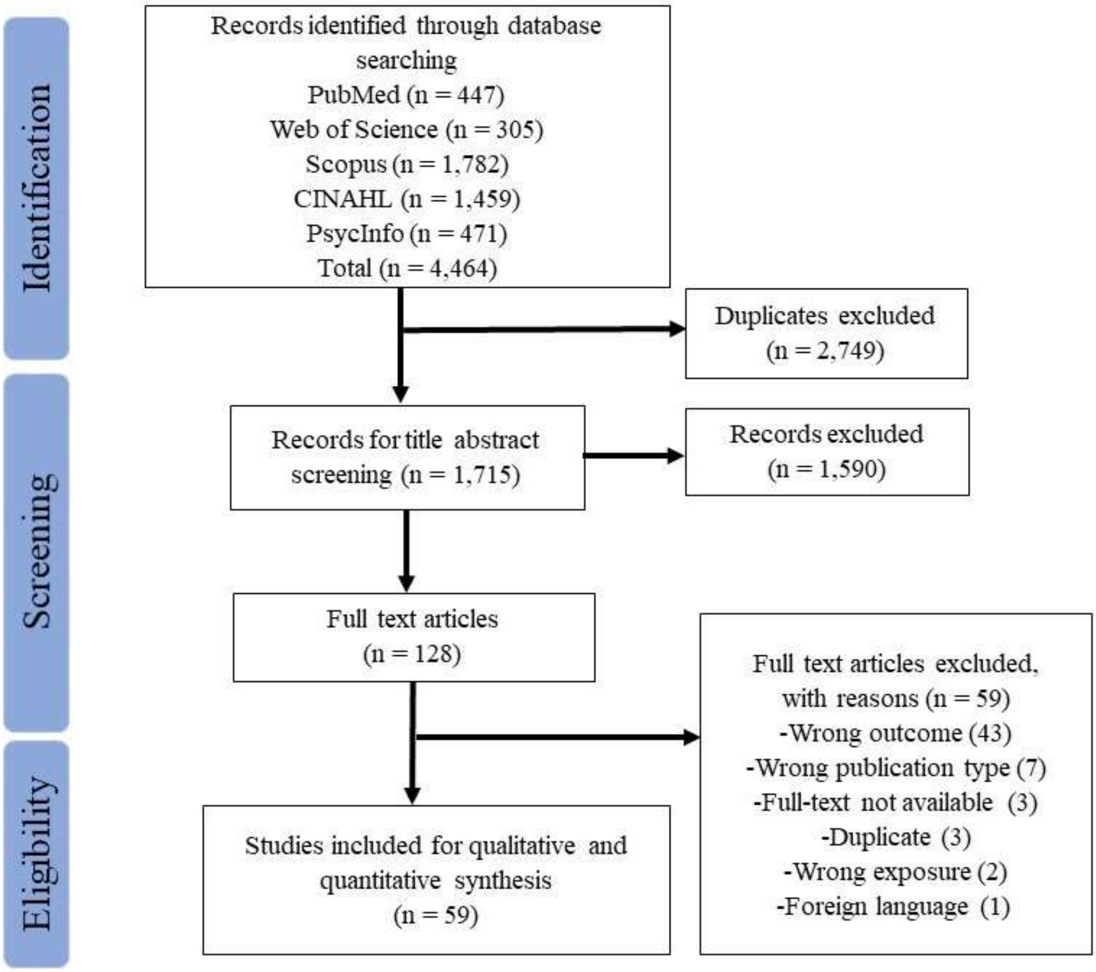


Figure 1. PRISMA flowchart of study selection for systematic review exploring the association between nature exposure and mental health during COVID-19.

Of the 59 studies, 48 (81%) had a cross-sectional design, four (7%) used a longitudinal design, three (5%) adopted a cohort design, three (5%) had an ecological design, and one (2%) used a Participatory Action Research (PAR) approach. All studies were conducted between January 2020 and May 2021. The total sample size across all included studies was 191,073, ranging from 25 participants (Olszewska-Guizzo et al., 2021) to 55,204 participants (Bu et al., 2021) in individual studies. Seven studies (11%) were conducted in multiple countries, while 24 (39%) were conducted in Europe, where UK (n = 4) and Italy (n = 4) studies were dominant. Eight studies were conducted in the U.S. (13%), and 17 (23%) studies were conducted in Asia, including seven from China. One study (2%) was conducted in each of the following countries: Australia, Mexico, and Brazil. The majority of the targeted samples were adult populations, followed by students, youth and adolescents.

3.2. Nature exposure assessments

Nature exposure assessments included availability, access, contact, and indoor exposures (Table 1). To simplify the interpretation, we classified the reported indicators into several groups: nature availability (e.g., satellite-derived vegetation indices, percentage of greenspace area), access to nature (e.g., access to outdoor greenspace, distance to greenspace), contact with nature (e.g., frequency of visit, time spent in nature, gardening activities, perceived greenery), and nature at home (e.g., green view from home, plants at home, presence of balcony, presence of garden). These classes were derived based on previous systematic reviews evaluating different aspects of nature exposure assessments (Holland et al., 2021; Labib et al., 2020; 2022).

3.2.1. Nature availability

Among our reviewed articles, twelve studies reported the nature availability indicators during COVID-19, which included the satellite-derived vegetation indices (e.g., NDVI, EVI), percentage of greenspace area, and tree canopy coverage (Cheng et al., 2021; Heo et al., 2021; Jato-Espino et al., 2022; Larson et al., 2022; LÃµhmus et al., 2021; Robinson et al., 2021; Samuelsson et al., 2021; Soga et al., 2020; Vos et al., 2022; Wortzel et al., 2021; Yao et al., 2022; Zhang et al., 2022). Several studies used different satellites (e.g., Landsat-8 Operational Land Imager, Sentinel-2) with varying resolutions (e.g., 30m, 10m) at different scales (e.g., city, residence), and they used different indices. Of these, two studies estimated the NDVI at multiple buffer distances (LÃµhmus et al., 2021; Robinson et al., 2021), one study used a single buffer distance (Soga et al., 2020), while other three studies estimated NDVI using census units (Cheng et al., 2021; Heo et al., 2021; Larson et al., 2022) (Table S5).

Multiple studies assessed the percentage of greenspace area in the neighborhood. Of these, three studies measured the greenspace area as the percentage of land cover with greenspace (Jato-Espino et al., 2022; Samuelsson et al., 2021; Vos et al., 2022), where one study used the CORINE land cover map at a European scale (Jato-Espino et al., 2022), one study conducted in Belgium used orthographic images for land cover map (Vos et al., 2022) and the remaining one obtained national land cover data from Swedish Environmental Protection Agency mapped on a 10 m resolution raster during the years 2017–2019 (Samuelsson et al., 2021). Two studies estimated park area as greenspace exposure using publicly available data (Larson et al., 2022; Yao et al., 2022), such as the Statistical Yearbook of Chinese Cities 2019 (Yao et al., 2022). Studies used multiple radius distances surrounding the greenspace area, urban park, and vegetative area ranging from 50-m to 1000-m (Jato-Espino et al., 2022; Vos et al., 2022). One study used greenspace area and abundance at 50-m, 100-m, 250-m, and 500-m distances (Robinson et al., 2021). Tree canopy density, as greenspace exposure, was reported in two studies (Wortzel et al., 2021; Zhang et al., 2022). Of these, one study estimated the results of tree canopy coverage as a measure of residential greenness using the World View-2 satellite imagery, with a resolution of 0.5 m derived in 2013 (Zhang et al., 2022), while the other study calculated the mean tree canopy density at 0-m, 100-m, 250-m, 500-m and 1000-m distance using the United States Department of Agriculture (USDA) Forest Service 2016 Tree Canopy Cover for the continuous United Stated data (Wortzel et al., 2021).

3.2.2. Access to nature

Twelve studies reported access to nature as an indicator for nature exposure assessment during COVID-19. Of these, five studies reported direct access to outdoor greenspace (e.g., outdoor nature, terrace, exteriors) (Groot et al., 2022; Hansmann et al., 2021; Kontsevaya et al., 2021; Mintz et al., 2021; Poortinga et al., 2021). One study reported accessibility to private green spaces from the lowest to the highest amount of private green space and the type of road where the house was located as a proxy for the natural outdoor environment (Spano et al., 2021). Nine of the twelve studies utilized self-reported surveys to measure access to nature. Distance to the nearest greenspace and blue space was the assessment method for seven of these studies. In China, the average distance from a residence to a park was recorded as 37.8 km (Chen & Liu, 2021), while most residents in Mexico reported living within a 10-minute walk of green space (Huerta & Utomo, 2021). A longitudinal study in the UK reported that the majority of residents lived within a 5-min walking distance from the nearest green space (Poortinga et al., 2021). Another cross-sectional study in Sweden calculated the Euclidean distances from the respondents' homes to the natural land cover they visited (Samuelsson et al., 2021). One study asked the participants whether the nearest green space was within walking distance (Oswald et al., 2021).

3.2.3. Contact with nature

Contact with nature during COVID-19 as an indicator for nature exposure assessment was reported in 37 studies in a variety of ways. In these studies, the amount of time spent in nature (e.g., park, garden), frequency of visits to nature, nature connectedness, usages of greenspace, perceived neighborhood greenery, garden activities, nature sound, and nature therapy were reported as indicators for nature contact. A total of 13 studies reported the time spent in different public and private greenspaces. Of these, five studies reported the time spent in private greenspaces (e.g., gardens) during COVID-19 (Basu et al., 2021; Bu et al., 2021; Lehberger et al., 2021; Samus et al., 2022; Sia et al., 2022).

Twelve studies reported time spent in nature during the COVID-19 period by directly asking participants about their time spent in nature (e.g., parks, greenspaces). On average, the maximum time spent in outdoor nature was reported 1.62 h/day in the USA (Browning et al., 2021), while the lowest exposure time (0≤60 minutes/week) was found in Singapore (Olszewska-Guizzo et al., 2021). Only one study compared the extent to which participants spent time in nature during the pandemic to pre-pandemic time. A study in the USA compared to time spent in outdoor nature during and post-lockdown period using three categories, including ‘no change’, ‘more often than a month ago’, and ‘less often than a month ago’ (Young et al., 2021).

Another important indicator for nature contact was the frequency of visits to nature (e.g., parks, gardens, forests, and greenspace), reported in 13 studies. Of these, nine studies reported the frequency of visits to nature during the pandemic period, while the remaining six studies assessed the changes in the frequency of visits to nature compared to pre-pandemic time. Of these, three studies reported a decline in nature visits at a significant rate during the pandemic period compared to pre-pandemic (Heo et al., 2021; Huerta & Utomo, 2021; Jackson et al., 2021b). One study in Sweden reported a 13% increase in nature visits during the COVID-19 pandemic compared to before the pandemic (LÃµhmus et al., 2021). One study compared the garden use frequency during the pandemic with before the pandemic time (Corley et al., 2021). Another cross-sectional study conducted in Belgium reported more than half of the participants visited nature more during the pandemic than the pre-pandemic time (Lenaerts et al., 2021). Three studies reported garden activities as a possible nature contact during COVID-19 (Lades et al., 2020; Samus et al., 2022; Theodorou et al., 2021).

Six studies assessed nature connectedness. Of these, four studies used different scales to assess nature connectedness, including 7-item Inclusion of Nature Self (INS) scale (Tomasso et al., 2021), a 6-item connection to nature (Jackson et al., 2021a), a 5-item nature connection scale (Mead et al., 2021), and a 14-item nature connectedness scale (Samus et al., 2022). The remaining two studies directly asked participants whether they were connected to nature during the last 24 hours (Friedman et al., 2022; Mintz et al., 2021). One study reported community gardening during lockdown compared with the pre-lockdown period (Kou et al., 2021). Further, only two out of six studies reported the changes in nature connection during COVID-19 to the pre-COVID-19 period (Friedman et al., 2022; Jackson et al., 2021a).

Four studies reported perceived neighborhood greenery (Dzhambov et al., 2021; Lenaerts et al., 2021; Oswald et al., 2021; Ribeiro et al., 2021). Two studies assessed the changed use of greenspace (e.g., parks, botanical gardens, balconies) (Larson et al., 2022; Pearson et al., 2021). A cross-sectional study reported changes in nature sound during the pandemic compared to pre-pandemic time (Garrido-Cumbrera et al., 2021) as a possible nature contact indicator. Other nature contact indicators including the quality of greenspace (Huerta & Utomo, 2021), nature experience activities (Jackson et al., 2021a), nature exercise and nature therapy (Sundara Keeren et al., 2021), and perceived nature deprivation (Tomasso et al., 2021) were reported in the literature.

3.2.4. Nature at home

While most studies used outdoor nature exposure as a measure of nature contact during COVID-19, some studies reported the presence of garden facilities and indoor greenery as indicators for nature at home exposure. The presence of a garden at facilities was considered a key element for nature contact during social distancing in nine studies. Of these, eight studies reported whether any garden was present in the living place during the pandemic time. One study reported the presence of gardens at a healthcare facility (Gola et al., 2021). However, the garden facility might have not been present in many houses because of their more urban living conditions, restricted neighborhood facilities, or lower socioeconomic status (England, 2020).

In that case, indoor greenery, such as the presence of a balcony, plants at home, or green views from a window, had the potential to replace the garden access and generated provisions for nature contact during the lockdown period (Labib et al., 2022). Such indoor greeneries were reported in sixteen studies. Of these, nine studies asked participants whether they had any balcony or yard, or terrace at their place of residence during lockdown time. Five studies quantified the number of plants present at home during the lockdown period. Of the total, five studies reported the green view from the window or home during COVID-19.

3.3. Narrative descriptions of associations between nature exposure and mental health

3.3.1. Anxiety

Fifteen studies (25%), including 13 cross-sectional study designs (Asim et al., 2021; Basu et al., 2021; Bourion-Bédès et al., 2021a; Bu et al., 2021; Corley et al., 2021; Dzhambov et al., 2021; Heo et al., 2021; LÃµhmus et al., 2021; Millán-Jiménez et al., 2021; Pouso et al., 2021; Sansal et al., 2021; Spano et al., 2021; Sundara Keeren et al., 2021), one cohort (Wortzel et al., 2021) and one longitudinal study design (Young et al., 2021) reported an association between the nature exposure and level of anxiety (Table 1). Of the total, five studies used the GAD-7 scale (Spitzer et al., 2006), three studies used GAD-2 (Kroenke et al., 2007), three used DASS-21 (Lovibond & Lovibond, 1995), one study used SCL-90 scale (Derogatis & Savitz, 1999), and the remaining three studies did not use any standard scale for assessing anxiety.

Among 15 studies on anxiety, three studies reported nature availability components such as EVI (Heo et al., 2021), NDVI (LÃµhmus et al., 2021), and tree canopy density (Wortzel et al., 2021) were not significantly associated with anxiety. Three studies reported a positive association between access to nature components such as access to a private greenspace (e.g., balcony, terrace, garden) and lower odds of anxiety (Dzhambov et al., 2021; Pouso et al., 2021; Spano et al., 2021). However, two studies found no direct access to a domestic private garden was associated with higher anxiety (Basu et al., 2021; Bourion-Bédès et al., 2021). Multiple studies reported a positive association between nature contact such as time spent in outdoor nature (e.g., garden) (Basu et al., 2021; Bu et al., 2021; Young et al., 2021), perceived neighborhood greenery (Dzhambov et al., 2021), and participating nature exercise & therapy program (Sundara Keeren et al., 2021) with reduced anxiety score. On the other hand, two studies reported an inverse correlation between outdoor nature and anxiety (Sansal et al., 2021; Young et al., 2021). However, several other studies did not report any association between nature contact, such as increased frequency of nature visitation (Corley et al., 2021; Heo et al., 2021; LÃµhmus et al., 2021) and gardening (Corley et al., 2021) with anxiety. Several studies reported a positive association between nature at home components such as greener or nature view from a window (Asim et al., 2021; Dzhambov et al., 2021; Pouso et al., 2021; Spano et al., 2021) and indoor plants with lower severity of anxiety (Asim et al., 2021). However, two studies did not find any association between them (Dzhambov et al., 2021; Spano et al., 2021).

Regarding the risk of bias assessment, five studies of anxiety showed a high risk of bias (Asim et al., 2021; Bu et al., 2021; Millán-Jiménez et al., 2021; Sansal et al., 2021; Sundara Keeren et al., 2021), four showed probably high risk of bias (Basu et al., 2021; LÃµhmus et al., 2021; Wortzel et al., 2021; Young et al., 2021) and the remaining six showed a low risk of bias (Bourion-Bédès et al., 2021a; Corley et al., 2021; Dzhambov et al., 2021; Heo et al., 2021; Pouso et al., 2021; Spano et al., 2021) (Table S2 & Table S3). Quality of evidence was “very low” due to a large amount of high to probably high risk of bias studies and unexplained substantial heterogeneity (supplementary material S3, Table S4).

3.3.2. Depression

Fifteen studies (25%) reported depression, of which 12 were cross-sectional design (Amerio et al., 2020; Asim et al., 2021; Basu et al., 2021; Bu et al., 2021; Dzhambov et al., 2021; Heo et al., 2021; LÃµhmus et al., 2021; Millán-Jiménez et al., 2021; Sarai Pouso et al., 2021; Samus et al., 2022; Sansal et al., 2021; Sundara Keeren et al., 2021), one cohort (Wortzel et al., 2021) and two longitudinal study design (Agnieszka Olszewska-Guizzo et al., 2021; Young et al., 2021) (Table 1). Four studies used the PHQ-9 scale (Spitzer et al., 1999), three used PHQ-2 (Kroenke et al., 2003), two used DASS-21 (Lovibond & Lovibond, 1995), one used DASS-42 (Uncu et al., 2007), two used CES-D (Roberts & Vernon, 1983), one used SCL-90 (Derogatis & Savitz, 1999), one used Becks Depression Inventory-II (BDI-II) (Beck et al., 1996), and the remaining one study did not use any standard scale for assessing depression.

Among the 15 studies, two studies reported no association between nature availability (NDVI, EVI) and depression (Heo et al., 2021; LÃµhmus et al., 2021). However, one cohort study reported a positive association between nearby greenness and a protective effect for depression (Wortzel et al., 2021). Multiple studies reported having access to livable outdoor spaces (e.g., private gardens, balconies, terraces)wasassociated with lower odds of depression (Amerio et al., 2020; Basu et al., 2021; S Pouso et al., 2021). Further, several studies reported a positive association between nature contact, such as time spent in outdoor nature (Basu et al., 2021; Bu et al., 2021; Sansal et al., 2021; Young et al., 2021), increased visitation to greenspace (LÃµhmus et al., 2021), participating in nature therapy and nature exercise program (Sundara Keeren et al., 2021) and lower depression. Another study found that decreased visitation to greenspace was associated with higher depression (Heo et al., 2021). However, multiple studies reported no significant association between nature contact and depression (A Olszewska-Guizzo et al., 2021; Samus et al., 2022). Further, multiple studies reported nature at home, such as having a greener view from a window, was associated with lower levels of depression (Amerio et al., 2020; Asim et al., 2021; Dzhambov et al., 2021; S Pouso et al., 2021).

Of the total, seven studies had a high risk of bias (Amerio et al., 2020; Asim et al., 2021; Bu et al., 2021; Millán-Jiménez et al., 2021; Olszewska-Guizzo et al., 2021; Sansal et al., 2021; Sundara Keeren et al., 2021), five had probably high risk of bias (Basu et al., 2021; LÃµhmus et al., 2021; Samus et al., 2022; Wortzel et al., 2021; Young et al., 2021) and the remaining three showed a low risk of bias (Dzhambov et al., 2021; Heo et al., 2021; Pouso et al., 2021) (Table S2 & Table S3). Quality of evidence was "very low" due to the high amount of high to probably high risk of bias studies and high inconsistency of effect measures (supplementary material S3, Table S4).

3.3.3. Stress

Thirteen studies (22%) reported an association between nature exposure and stress, including nine cross-sectional designs (Basu et al., 2021; Bourion-Bédès et al., 2021; Jato-Espino et al., 2022; LÃµhmus et al., 2021; Mintz et al., 2021; Pearson et al., 2021; Ribeiro et al., 2021; Sansal et al., 2021; Sundara Keeren et al., 2021), two cohorts (Vos et al., 2022; Wortzel et al., 2021) and two ecological study design (Robinson et al., 2021; Yao et al., 2022) (Table 1). Of these, three studies used a 10-item perceived stress scale (PSS) (S. Cohen et al., 1983), one study used a 6-item PSS (Sheldon Cohen & Williamson, 1988), two used DASS-21 (Lovibond & Lovibond, 1995), one used DASS-42 (Uncu et al., 2007), one study used 6-item short State-Trait Anxiety Scale (STAI) (Marteau & Bekker, 1992), one study reported 5-item interactive assessment of COVID-19 related stress, one study used mental stress index, and the remaining three studies reported self-reported 1-item question for measuring stress.

Multiple studies reported a positive association between nature availability (e.g., higher residential greenness) and lower stress (LÃµhmus et al., 2021; Robinson et al., 2021; Vos et al., 2022; Yao et al., 2022). In contrast, one study showed a negative association between them (Jato-Espino et al., 2022). However, several studies did not find any significant impact of nature availability, such as nearby greenspace (Wortzel et al., 2021) and distance to greenspace (Robinson et al., 2021), on stress during COVID-19. Several studies found a positive association between nature contact, such as time spent in the home garden or outdoor spaces (Basu et al., 2021; Sansal et al., 2021), frequent visits to nature (LÃµhmus et al., 2021), increased usage of the backyard or porch (Pearson et al., 2021), nature near home (Mintz et al., 2021), public nature space (Ribeiro et al., 2021), participating week-long nature therapy and nature-exercise program (Sundara Keeren et al., 2021) and stress reduction. However, studies reported community greenspaces (Ribeiro et al., 2021) and being in nature (Mintz et al., 2021) were not associated with stress. Nature at home, such as indoor plants, was linked to lower stress levels (Ribeiro et al., 2021), while outdoor plants on a balcony had no such association (Ribeiro et al., 2021). Further evidence showed that limited access to outdoor spaces increased the likelihood of developing stress (Basu et al., 2021; Bourion-Bédès et al., 2021a).

Of the total, three had a high risk of bias (Sansal et al., 2021; Sundara Keeren et al., 2021; Yao et al., 2022), six had probably high risk of bias (Basu et al., 2021; Jato-Espino et al., 2022; LÃµhmus et al., 2021; Robinson et al., 2021; Vos et al., 2022; Wortzel et al., 2021) and the remaining four showed a low risk of bias (Bourion-Bédès et al., 2021a; Mintz et al., 2021; Pearson et al., 2021; Ribeiro et al., 2021) (Table S2 & Table S3). Quality of evidence was "very low" due to the high amount of high to probably high risk of bias studies and high inconsistency of effect measures (supplementary material S3, Table S4).

3.3.4. General mental health problems

Thirteen studies (22%) reported an association between nature exposure and general mental health problem, including eleven cross-sectional study designs (Browning et al., 2021; Chen & Liu, 2021; Corley et al., 2021; Hubbard et al., 2021; Kou et al., 2021; Lenaerts et al., 2021; Marques et al., 2021; Oswald et al., 2021; Ribeiro et al., 2021; Soga et al., 2020; Theodorou et al., 2021; Xie et al., 2020; Zhang et al., 2022) and one Participatory Action Research (PAR) design (Kou et al., 2021) (Table 1). Of these, three studies reported the GHQ-12 scale (Goldberg et al., 2000), one study each reported the K6 scale (Kessler et al., 2002), SCL-K-9 scale (Klaghofer & Brähler, 2001), PHQ-4 (Kroenke et al., 2009), DASS-21 (Lovibond & Lovibond, 1995), MHC-SF (Keyes et al., 2008) and K10 (Furukawa et al., 2003) and the remaining five studies did not use any standard scale for measuring the general mental health problem.

Two studies reported a positive association between nature availability, such as tree cover (Zhang et al., 2022) and living >300m from a greenspace (Oswald et al., 2021) and lower mental health. In contrast, two studies found no association between them (Marques et al., 2021; Soga et al., 2020). Three studies reported having access to a garden/balcony/yard or gardening activities was associated with lower odds of mental health (Hubbard et al., 2021; Marques et al., 2021; Theodorou et al., 2021), while two studies found no association between them (Oswald et al., 2021; Ribeiro et al., 2021). Multiple studies reported a positive association between nature contacts, such as the increased amount of time spent in outdoor nature or greenspace (Browning et al., 2021; Oswald et al., 2021; Xie et al., 2020), frequent visits or increased usage of nature (Corley et al., 2021; Hubbard et al., 2021; Lenaerts et al., 2021; Marques et al., 2021), gardening (Kou et al., 2021), higher perceived green neighborhood (Oswald et al., 2021) and better mental health. However, two studies did not find an association between time spent in greenspace (Hubbard et al., 2021), perceived neighborhood greenery (Ribeiro et al., 2021), and general mental health problems. Three studies reported nature at home, such as having a greener view, was associated with less mental health problems (Marques et al., 2021; Ribeiro et al., 2021; Soga et al., 2020), while plants at home were found not associated with mental health problems (Marques et al., 2021; Ribeiro et al., 2021).

Of the total, five studies had a high risk of bias (Chen & Liu, 2021; Hubbard et al., 2021; Kou et al., 2021; Theodorou et al., 2021; Xie et al., 2020), two had a probably high risk of bias (Browning et al., 2021; Soga et al., 2020) and the remaining six studies showed a low risk of bias (Corley et al., 2021; Lenaerts et al., 2021; Marques et al., 2021; Oswald et al., 2021; Ribeiro et al., 2021; Zhang et al., 2022) (Table S2 & Table S3). Quality of evidence was "very low" due to high and probably high risk of biased studies and high inconsistency of effect measures (supplementary material S3, Table S4).

3.3.5. Sleep disturbances

Six studies (10%) reported sleep disturbances and nature associations during COVID-19. Of these, five were cross-sectional study designs (Corley et al., 2021; Kontsevaya et al., 2021; Millán-Jiménez et al., 2021; Sansal et al., 2021; Spano et al., 2021), and one adopted longitudinal design (Okely et al., 2021).

Sleep disturbances were assessed using the 1-item Pittsburgh Sleep Quality Index (Buysse et al., 1989), 3-item sleep quality, 1-item sleep problem increase, 1-item on insomnia, and the remaining two studies quantitatively determined the sleep duration. One study found better access to a garden was associated with a lower increase in sleep problems during COVID-19 (Spano et al., 2021), while two studies with a high risk of bias found no association between access to greenspace or outdoor spaces and sleep problem (Kontsevaya et al., 2021; Okely et al., 2021). Studies have also reported that increased usage of gardens during COVID-19 compared to the pre-pandemic period (Corley et al., 2021), time spent in the outdoors during lockdown (Sansal et al., 2021), greener view from home and plants at home (Spano et al., 2021) was associated with lower increases in sleep problems during COVID-19.

Of the total, four had high risk of bias (Kontsevaya et al., 2021; Millán-Jiménez et al., 2021; Okely et al., 2021; Sansal et al., 2021), and the remaining two had a low risk of bias (Table S2 & Table S3). Quality of evidence was "very low" due to the high amount of high to probably high risk of bias studies and high inconsistency effect measures (supplementary material S3, Table S4). No meta-analyses for sleep disturbances were available due to heterogeneity in exposure-outcome combinations and inconsistent reporting of effect estimates.

3.3.6. Mood states

Four studies (7%) reported mood states and nature associations during the COVID-19 period. Of these, three were cross-sectional (Gola et al., 2021; Jato-Espino et al., 2022; Millán-Jiménez et al., 2021), and one was longitudinal study design (Olszewska-Guizzo et al., 2021). Two studies used a profile of mood state (POMS) scale (Shacham, 1983), and the remaining two studies did not use any standard scale for assessing mood.

A cross-sectional study in Spain reported a negative association between closeness to green infrastructure and mood (Jato-Espino et al., 2022), while a longitudinal study in Singapore did not find any association between nature exposure and mood disturbances (Olszewska-Guizzo et al., 2021). One study reported that a short break in green space helped to rejuvenate hospital staff during a time of crisis (Gola et al., 2021), while another study found enjoying open spaces provided a sense of peace (Millán-Jiménez et al., 2021).

Of the total, three studies reported a high risk of bias (Gola et al., 2021; Millán-Jiménez et al., 2021; Olszewska-Guizzo et al., 2021) and the remaining one had probably high risk of bias (Jato-Espino et al., 2022) (Table S2 & Table S3). Quality of evidence was "low" due to the high amount of high to probably high risk of bias studies (supplementary material S3, Table S4). Due to inconsistencies in reporting effect sizes and the lack of consistent exposure-outcome pairings, no meta-analyses were available for mood states.

3.3.7. Positive and Negative affect

Three cross-sectional studies (5%) reported positive and negative affect during COVID-19 (Lades et al., 2020; Mintz et al., 2021; Samus et al., 2022). The 3-item positive affect, 6-item negative affect, and positive and negative affect (PANAS) schedule (Watson et al., 1988) were used for assessing the positive and negative affect of the participants during COVID-19.

Studies reported that gardening (Lades et al., 2020) and strong nature connectedness (Samus et al., 2022) were associated with the largest positive affect. Further, a study found nature near the home and nature from windows were associated with lower levels of negative affect (Mintz et al., 2021). In contrast, in one study, nature connectedness was not associated with lower negative affect (Samus et al., 2022).

Among the three studies, one each had a high (Lades et al., 2020), probably high (Samus et al., 2022), and low risk of bias (Mintz et al., 2021) (Table S2 & Table S3). Quality of evidence was "very low" due to high and probably high risk of bias studies, and the lack of sufficient studies to make imprecision or decision-based on each side of the confidence intervals was associated with different judgments (supplementary material S3, Table S4). Meta-analyses were not available for positive and negative affect because of discrepancies in reporting effect sizes and the lack of consistent exposure-outcome pairings.

3.3.8. Loneliness

Two studies (3%), including one cross-sectional design (Soga et al., 2020) and one cohort study design (Groot et al., 2022), reported loneliness and nature exposure during COVID-19. Of these, one study used the UCLA loneliness scale (Russell, 1996), and the remaining one used a 1-item question for determining loneliness during COVID-19.

Nature availability, such as higher greenness, was not associated with loneliness (Soga et al., 2020). However, more frequent visitation to greenspace and having a green view from home were associated with lower loneliness (Soga et al., 2020). Further, no access to outdoor nature was associated with higher loneliness during the pandemic period (Groot et al., 2022).

Of the two studies, one had high risk of bias (Groot et al., 2022), and the remaining one showed probably high risk of bias (Soga et al., 2020) (Table S2 & Table S3). Quality of evidence was "very low" due to all studies reported a high/probably risk of bias and a lack of sufficient studies to make imprecision or decision-based on each side of the confidence intervals was associated with different judgments (supplementary material S3, Table S4). Meta-analyses were not performed due to heterogeneity in exposure-outcome pairs.

3.3.9. Emotional distress

Two cross-sectional studies (3%) reported emotional problems during the COVID-19 period (Friedman et al., 2022; Larson et al., 2022). Emotional distress was determined using Strengths and Difficulties Questionnaires (SDQ) (Goodman, 1997) and a 5-item visual analogue scale (VAS) (Winefield et al., 2012).

Nature availability, including higher greenness and areas of the local park, was not associated with emotional distress (Larson et al., 2022). Living in counties in the U.S. with a national/state park was associated with less emotional distress while reducing park use was associated with more emotional distress (Larson et al., 2022). However, changes in nature connection positively influenced the emotional problems among children during COVID-19 (Friedman et al., 2022).

Of the two studies, one had high risk (Friedman et al., 2022), and the remaining one had low risk (Larson et al., 2022) of bias (Table S2 & Table S3). Quality of evidence was "very low" due to the high inconsistency of effect measures and lack of sufficient studies to make imprecision or decision-based on each side of the confidence intervals was associated with different judgments (supplementary material S3, Table S4). The lack of consistency in reporting effect sizes and the absence of consistent exposure-outcome pairings prevented a meta-analysis for emotional distress.

3.3.10. Mental well-being

Seventeen studies (29%) reported an association between nature exposure and mental well-being, including 14 cross-sectional study designs (Garrido-Cumbrera et al., 2021; Hansmann et al., 2021; Huerta & Utomo, 2021; Jackson et al., 2021a, 2021b; LÃµhmus et al., 2021; Lee et al., 2021; Lehberger et al., 2021; Mead et al., 2021; Pérez-Urrestarazu et al., 2021; Samuelsson et al., 2021; Sia et al., 2022; Tomasso et al., 2021; Zhuo & Zacharias, 2021), one cohort (Groot et al., 2022), one longitudinal (Poortinga et al., 2021) and one ecological study design (Robinson et al., 2021). Mental well-being of the participants was assessed using the WHO-5 scale (WHO REGIONAL OFFICE FOR EUROPE, 1998), 14-item Warwick-Edinburgh Mental Wellbeing Scale (Weich et al., 2007), 4-item modified subjective well-being (Hansmann et al., 2021), RAND-36 scale (Hays & Morales, 2001), SF-36 items (Idler & Benyamini, 1997), psycho Social Well-Being Index Short Form (PWI-SF) (Koh et al., 2005), emotional well-being (Pérez-Urrestarazu et al., 2021), five domains of Harvard Flourishing Index (WWziak-Biaaowolska et al., 2018), GHQ-12 (Goldberg et al., 2000), different number of mental well-being items and mental resilience using SYRSS-10 scale (Sia et al., 2022).

Multiple studies reported a positive association between nature availability, such as higher residential greenness (LÃµhmus et al., 2021; Robinson et al., 2021), distance to the nearest greenspace (Poortinga et al., 2021), and better mental health. However, several studies reported distance to greenspace (Huerta & Utomo, 2021; Lee et al., 2021; Robinson et al., 2021) and greenspace presence and abundance at multiple distances (except 500-m) (Robinson et al., 2021) were not associated with mental well-being. Several studies reported a significant association between access to nature, such as higher quality of greenspace (Huerta & Utomo, 2021), access to public green space (e.g., a park or woodland) and private green space (a private garden) (Poortinga et al., 2021), access to outdoor nature space (Groot et al., 2022; Hansmann et al., 2021) and better mental well-being. Several studies reported a positive association between nature contact, such as time spent at forest sites (Lee et al., 2021), length of weekly gardening time (Sia et al., 2022), spending more time in greenspace and garden (Lehberger et al., 2021), visiting nature often (vs. seldom) (Huerta & Utomo, 2021; LÃµhmus et al., 2021), continued participation in nature-based activities (Jackson et al., 2021a, 2021b), improved nature sound (Garrido-Cumbrera et al., 2021) and increased mental well-being. However, several studies found no association between components of nature contact and mental well-being (Jackson et al., 2021a, 2021b; Lee et al., 2021; Mead et al., 2021; Pérez-Urrestarazu et al., 2021; Tomasso et al., 2021). Further, nature at home, such as the presence of private space, yard, or terrace, showed negative relation with mental well-being (Zhuo & Zacharias, 2021).

Six studies of mental well-being showed a high risk of bias (Garrido-Cumbrera et al., 2021; Groot et al., 2022; Hansmann et al., 2021; Mead et al., 2021; Pérez-Urrestarazu et al., 2021; Sia et al., 2022) (Supplementary Table 2). Five had probably high risk of bias (Jackson et al., 2021a, 2021b; LÃµhmus et al., 2021; Robinson et al., 2021; Zhuo & Zacharias, 2021), and the remaining six studies showed a low risk of bias (Huerta & Utomo, 2021; Lee et al., 2021; Lehberger et al., 2021; Poortinga et al., 2021; Samuelsson et al., 2021; Tomasso et al., 2021) (Table S2 & Table S3). Overall, the quality of evidence was "very low" due to high risk and probably high risk of bias studies, and high inconsistency of effect measures was associated with different judgments (supplementary material S3, Table S4).

3.3.11. Happiness

Four studies (7%), including three cross-sectional stud designs (Millán-Jiménez et al., 2021; Mintz et al., 2021; Soga et al., 2021) and one ecological design (Cheng et al., 2021) reported happiness as mental health outcome during COVID-19. Three studies used a single measure of happiness; one study used a standard scale such as the subjective happiness scale (Lyubomirsky & Lepper, 1999).

Nature availability, including parks with higher NDVI values, leads to higher happiness for residents (Cheng et al., 2021). However, higher greenness was not associated with resident happiness during COVID-19 (Soga et al., 2020). One study did not find any association between nature near home, nature from windows, or nature connection and happiness (Mintz et al., 2021). On the other hand, frequent visits to greenspace and having a green view from the home were associated with residents' levels of happiness (Soga et al., 2020).

Of the four, one study reported a high risk of bias (Millán-Jiménez et al., 2021), two had probably high risk of bias (Cheng et al., 2021; Soga et al., 2020), and the remaining one showed a low risk of bias (Mintz et al., 2021) (Table S2 & Table S3). Quality of evidence was "very low" due to high amount of studies reported high/probably high risk of studies, higher inconsistency of effect measures, and the lack of sufficient studies to make imprecision or decision based on each side of the confidence intervals was associated with different judgments (supplementary material S3, Table S4). Meta-analysis was not done due to inconsistent effect size reporting and exposure-outcome pairings.

3.3.12. Life satisfaction

Three (5%) cross-sectional studies reported life satisfaction (Bu et al., 2021; Lehberger et al., 2021; Soga et al., 2021). Life satisfaction was assessed using an 11-item Life Satisfaction Index-A (LSI-A) (Liang, 1984) and a 1-item life satisfaction measure (Blanchflower et al., 2013).

More frequent visits to greenspace (Soga et al., 2020), increased gardening (Bu et al., 2021), and having a green view were associated with increased life satisfaction. In Australia, it was not associated with life satisfaction. However, higher greenness (Soga et al., 2020), having a garden, and spending more time in greenspace (Lehberger et al., 2021) were not associated with life satisfaction.

Of the total, one study had high risk of bias (Bu et al., 2021), one had probably high risk of bias (Soga et al., 2020), and the remaining one had a low risk of bias (Lehberger et al., 2021) (Table S2 & Table S3). Quality of evidence was "very low" due to the high amount of studies reported high to probably high risk of bias and high inconsistency of effect measures (supplementary material S3, Table S4). We did not perform a meta-analysis due to a lack of sufficient studies.

3.4. Meta-analyses of associations between nature exposure and mental health

Although cross-study comparisons were difficult due to the highly variable nature of the study designs and focal variables, meta-analyses were available for select combinations of four mental health outcomes and five nature exposure types. The source of the data used in the meta-analyses is available in **Table S6**.

3.4.1. Anxiety

Meta-analyses of anxiety were restricted to nature at home exposures (presence of gardens or green views from the window) (Bourion-Bédès et al., 2021b; Dzhambov et al., 2021; S Pouso et al., 2021). The presence of a garden was associated with reduced levels of anxiety [(Pooled odds ratio [OR] = 0.74, 95% CI = 0.64-0.87), I^2=0%, N = 2] (**Figure S1A**). We did not observe evidence of associations between anxiety and green views from windows [(Pooled OR = 0.79, 95% CI = 0.29-2.15), I^2=85%, N = 2] (**Figure S1B**).

3.4.2. Depression

Meta-analyses of depression were restricted to access to a garden, time spent in greenspace, or green views from home. Access to a garden was associated with reduced depression [(Pooled OR = 0.71, 95% CI = 0.61-0.82), I^2=0%, N = 3] (**Figure S1C**). We did not observe evidence of significant associations between time in greenspace and depression [(Pooled OR = 0.02, 95% CI = -0.85-0.89), I^2=97%, N = 2] (**Figure S1D**) or a window view of nature and depression [(Pooled OR = 0.83, 95% CI = 0.66-1.06), I^2=73%, N = 3] (**Figure S1E**).

3.4.3. General mental health

Meta-analyses of general mental health were restricted to measures of nature visitation frequency, access to a garden, and distance to blue or green space. Higher frequencies of greenspace visits were associated with better general mental health [(Pooled OR = 0.11, 95% CI = 0.03-0.38), I^2=82%, N = 2] (**Figure S1F**). We did not observe evidence of significant associations between access to gardens and general mental health [(Pooled OR = 1.04, 95% CI = 0.17-6.19), I^2=82%, N = 2] (**Figure S1G**) or distance to green/blue space and general mental health [(Pooled OR = 1.17, 95% CI = 0.71-1.95), I^2=58%, N = 2] (**Figure S1H**).

3.4.4. Mental well-being

Meta-analyses of mental well-being were restricted to measures of nature visitation frequency and distance to greenspace. Higher frequencies of visits to greenspace were associated with higher mental well-being [(Pooled standardized beta estimate [ES] = 0.10, 95% CI = 0.07-0.14), I^2=0%, N = 2] (**Figure S1I**). We did not observe evidence of associations between distance to greenspace and mental well-being [(Pooled OR = 0.98, 95% CI = 0.72-1.34), I^2=26%, N = 3] (**Figure S1J**).

3.5. Risk of bias and quality of evidence

Twenty-one studies (35% of the total) had a low risk of bias. Another 14 (24% of the total) had a probable high risk of bias, and 24 (41% of the total) had a high risk of bias (summary in **Table S2;** justifications in **Table S3**). The risk of bias for individual studies is presented in Figure 2. Recruitment strategies were predominantly rated as low risk of bias (74% of studies). All studies were rated as 'low' risk of bias for blind assessment. Nearly 45% of studies rated exposure assessment as 'probably low' risk of bias. However, in some cases, studies rated exposure assessment as 'high' risk of bias (25% of studies). Confounding was predominantly rated as 'probably low' risk of bias (63% of studies). Incomplete data, selective reporting, conflicts of interest, and other biases were predominantly rated as 'low' risk of bias, respectively. Out of 48 cross-sectional studies, 19 studies (39%) rated a 'high' risk of bias, while 42% (n = 20) rated a 'low' risk of bias. On the other hand, 2 cohort studies out of 3 rated as 'probably high' risk of bias. Further, two out of three ecological studies rated a 'probably low' risk of bias, and two out of four longitudinal studies rated a 'high' risk of bias. Since some of the approaches for evaluating exposure to greenness in the study did not account for the variety of plant life, exposure assessment was the domain with the highest risk of bias. In addition, several studies failed to assess the buffer distance surrounding the greenspace, green space quality or accessibility, and time spent in the green space area.

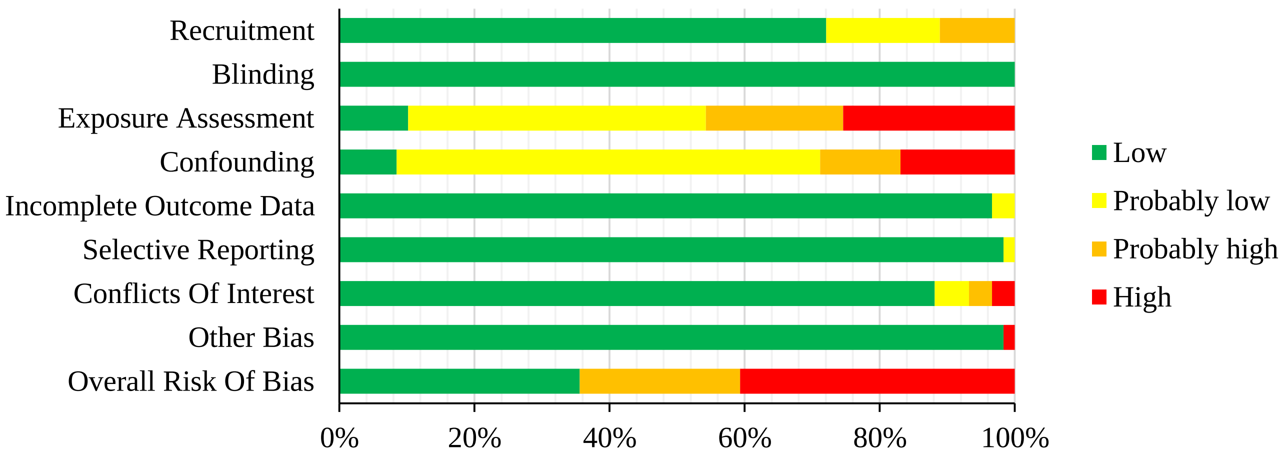


Figure 2. Summary of risk of bias for individual studies included in the review of exploring associations between nature exposure and mental health during the COVID-19 pandemic.

A justification for using a consistent measure of bias across studies has been outlined in **Table S4**, and outlining the specifics of each study's bias rating have been included in **Supplementary Material, S3**. Total quality scores by the outcome are shown with the corresponding outcome category in Table S5. We categorized the outcome depending on the nature of the outcomes they reported. All studies' outcomes (12 out of 12) were rated as "very low" quality of evidence.

4. Discussion

Although several previous reviews have examined the evidence regarding associations between nature exposure and mental health during the COVID-19 pandemic (Labib et al., 2022; Nigg et al., 2021), this is the first study to conduct a robust review of these relationships that accounts for the risk of bias and the quality of evidence presented. Fifty-nine articles published over nearly two-and-half years of the pandemic were evaluated, assessing 12 unique mental health outcomes accounting for up to four different dimensions of nature exposure: nature availability, access to nature, contact with nature, and nature at home. While we observed an impressive breadth of conceptualization and analysis, most relationships between nature and mental health were only supported by "very low" quality of evidence based on the GRADE rating system. The quality ratings were downgraded due to bias, inconsistency in evidence, and imprecision in evidence, with other downgrading and upgrading quality categories having no effect (e.g., indirectness, the magnitude of effect). Only 35% of studies had a low risk of bias. Despite constraints associated with the current quality of evidence, this study was also the first to conduct a series of meta-analyses across nature exposure dimensions and mental health outcomes during COVID-19, supporting that higher direct nature contact (i.e. higher visitation to natural areas, presence of nature at home) reduced some negative mental health outcomes and improved mental health and wellbeing. However, general poor quality limited our ability to conduct meta-analyses on many important outcomes (e.g., perceived stress, sleep, or loneliness) and hindered the generalizability of the meta-analyses we were able to conduct.

Several limitations underlie the poor quality and high bias associated with nature and mental health research during the COVID-19 pandemic. Consistent with research before the pandemic (Holland et al., 2018; Zhang et al., 2021), we observed a high reliance on cross-sectional research designs (81% of studies) and found only two longitudinal studies that objectively measured green space visitation, which inhibits causal inferences. There were also several studies that used inherently biased forms of convenience sampling (Babbie, 2013). Beyond research design, inconsistent and inadequate operationalization during instrumentation and analysis resulted in both heterogenous exposure assessments and weak control of confounding sources of variation in mental health outcomes, which introduced at least probably high bias to over 40% and 25% of studies, respectively. These issues are resolvable in future research by using appropriate scales for nature exposure and analytical designs that are consistent with existing theoretical understanding and empirical research. Lastly, inconsistencies in the reporting of effect estimates also inhibited meta-analyses for outcomes associated with multiple studies, such as perceived stress (Mintz et al., 2021; Ribeiro et al., 2021). While our review sheds light on several limitations within existing research, it may serve as a resource for navigating the many studies conducted on the nature-health relationship during COVID-19 based on exposure assessment, outcome, and quality.

The quality of evidence was high enough to conduct meta-analyses on four mental health outcomes potentially associated with nature exposure during the pandemic: anxiety, depression, general mental health, and mental well-being. Even though we could only pool a handful of studies, which limits the stability and generalizability of the meta-estimates, we found that the ownership or presence of a garden was associated with lower anxiety and depression. We also found that a higher frequency of visitation to nature was inversely associated with poor mental health and positively associated with mental well-being. Natural environments, especially gardens, may have served as unique outlets in the COVID-19 context for solitary or family activities that helped alleviate situation-specific stressors (Theodorou et al., 2021) while helping people and communities adhere to various safety precautions throughout the pandemic. While 16 studies assessed green views during COVID-19 and other reviews have noted consistent support for their positive effect on mental health (Labib et al., 2022), both meta-analyses using this measure were null. Therefore, gardens should be distinguished as uniquely important forms of nature at home, with these results providing broader support for the benefits of direct nature contact compared to indirect contact (Markevych et al., 2017).

In total, six meta-analyses across all four nature exposure measures resulted in null effects with no statistically significant observations across the nature availability and access to nature dimensions on any mental health outcome. In contrast with the positive outcomes from more frequent exposure, these null effects may reveal that nature availability and accessibility may only improve mental health if they result in actual exposure, consistent with the observations on gardens compared to green views. Amidst COVID-19 restrictions in particular, opportunity alone may have had less of a direct relationship with nature contact compared to before the pandemic (Soga et al., 2020). However, it remains possible that the null effects we observed were due to bias, poor quality, and a low quantity of existing evidence. No meta-analyses supported that spending time in or having access to nature and green spaces negatively influenced mental health, complementing other evidence that suggests natural areas posed minimal risk to broader physical and biological health concerns like COVID-19 infection (Bulfone et al., 2021; Heckert & Bristowe, 2021; Lin et al., 2023).

Our analyses and evaluation complement existing systematic (Labib et al., 2022) and scoping reviews (Heckert & Bristowe, 2021; Nigg et al., 2021) conducted throughout the pandemic on the effects of nature and green spaces on mental health. These effects also reinforce pre-COVID-19 research that observed similar health outcomes in more general contexts (Lackey et al., 2021). Building on a model proposed by (Markevych et al., 2017), (Astell-Burt et al., 2022) focused on loneliness, which many people may experience in times of social distancing, to describe how experiences and opportunities in natural areas interact with individual and place-based differences to impact health and wellbeing through four broad domains: building capacities, restoring capacities, reducing harm, and causing harm. These pathways are consistent with theoretical frameworks explaining the restorative benefits of natural environments, including attention restoration (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995) and stress reduction theories (Ulrich et al., 1991). The positive health outcomes from nature exposure are likely derived through several pathways conceptualized and analyzed by (Hartig et al., 2014) and (Zhang et al., 2021), including exposure to better air quality, increased physical activity, higher social contact and interaction, and reductions in stress. Collectively, these underlying theoretical and conceptual foundations may explain the pathways and processes that support the relationships observed in the present study between direct nature contact and improved mental health. Notably, the importance of these health promotion pathways might have been magnified during the COVID-19 pandemic, with outdoor environments' exhibiting higher levels of perceived and objective relative safety to indoor environments(Bulfone et al., 2021; Kim & Kang, 2021). As a result, the value of these spaces for physical and social activity grew while indoor areas were regulated or deemed unsafe.

Despite the theoretical, conceptual, and analytical foundation supporting the effects of nature on mental health and the large number of studies conducted during COVID-19, there are ample opportunities for higher-quality future research. While four primary effects were supported through meta-analyses, more than 40 other potential pathways using the outcomes and nature exposure measures considered in this review lacked substantial support. Separately, empirical work examining context-specific ramifications of the pandemic on nature exposure (e.g., social distancing, park regulations) and mental health during large-scale, stressful events may also help extend the field beyond its traditional pathways. To effectively study new pathways, researchers may examine how shifts in human-nature interactions due to pandemic-related changes in opportunity, capability, and motivation influenced mental health outcomes (Soga et al., 2020) or test nature's ability to facilitate positive outcomes during stressful events through resilience (Zautra et al., 2010; Zimmerman & Arunkumar, 1994) or post-traumatic growth (Waters et al., 2022). At a systemic level, limitations in existing research reflect the importance of integrating nature exposure and health metrics into long-term, systematic data collection approaches that persist during times of stability and crisis. Such designs could have benefitted research during the COVID-19 pandemic in three ways. First, by providing objective baseline metrics from before the pandemic, enhancing researchers' ability to detect meaningful change. Second, by reducing scrambling and impromptu innovation at the beginning of the pandemic to improve research design. Third, by improving understanding of how nature exposure and healthy relationships may have shifted during different phases of the pandemic (e.g., comparisons of the lockdown period to the post-vaccine period). Instituting longer-term projects now could pave the way for improved insights during future crises.

5. Conclusion

This study joins a growing set of reviews and meta-analyses in the broader field of research examining links between nature exposure and health that are constrained from drawing concrete conclusions due to bias and quality concerns (e.g., (Astell-Burt et al., 2022; Zare Sakhvidi et al., 2022; Zhang et al., 2021). Even minor adjustments, such as improving the consistency of nature exposure's instrumentation, providing clear estimates of effects and effect sizes, and controlling for confounding could substantially reduce bias. Ultimately, the overall quality of nature exposure research during COVID-19 (and after) is contingent upon better designs that use random sampling and longitudinal approaches. Despite the constraints, we did observe – based on narrative synthesis and meta-analyses of previous research – that exposure to nature positively impacted multiple dimensions of mental health. The strongest and most reliable evidence from meta-analyses revealed that two specific types of nature exposure – spending time in nature and gardening – yielded the most consistent benefits. Although there is a critical need for more research on these relationships, growing evidence suggests that promoting direct interaction with the natural world during stressful events may be a helpful strategy for policymakers and practitioners seeking to improve public health.

Table 1. Summary of the characteristics of studies included in the review of research exploring associations between nature exposure and mental health during the COVID-19 pandemic (alphabetical order).

Sl.	Author, year, country	Design, sample size	Nature exposure assessment	Outcome (Mental health assessment scale)	Main findings
1	(Amerio et al., 2020); Italy	Cross-sectional N = 8177	Presence of a livable outdoor space (balcony or garden); green view from window; quality of views	Depression (PHQ-9)	Having a green view reduced the odds of moderate-severe depression. Having a poor-quality view increased the odds of moderate-severe depression.
2	(Asim et al., 2021); India	Cross-sectional N = 432	Plants at house; Green view from window	Depression (CES-D); Anxiety (GAD-7)	Having a better green view was associated with lower anxiety and depression. Having a better green view was associated with lower depression risk.
3	(Basu et al., 2021); India	Cross-sectional N = 408	Presence of home garden; Time spent in home garden	Depression, Anxiety, Stress (DASS-21)	Having a home garden and time spent in home garden reduced anxiety, stress, and depression.
4	(Bourion-Bédès et al., 2021a); France	Cross-sectional N = 3936	Access to private outdoor space (balcony courtyard, terrace, or garden)	Anxiety (GAD-7)	No access to private outdoor space (e.g., garden, balcony) during lockdown was associated with severe anxiety.
5	(Bourion-Bédès et al., 2021b); France	Cross-sectional N = 3764	Access to private outdoor space (balcony courtyard, terrace, or garden)	Perceived Stress Scale (PSS-10)	No access to private outdoor space (e.g., garden, balcony) during lockdown was associated with high perceived stress.
6	(Browning et al., 2021); USA	Cross-sectional N = 2534	Time spent in outdoors (at a park, on a greenway/trail, in a neighborhood/yard, etc.)	General mental health	Increasing time spent (at last 2hrs) in outdoor nature experienced a lower level of mental health problems.
7	(Bu et al., 2021); UK	Cross-sectional N = 55204	Time spent in gardening	Depression (PHQ-9); Anxiety (GAD-7); Life satisfaction (1-item)	Increasing time spent in gardening (more than 30 minutes) was associated with reduced anxiety, depression, and higher life satisfaction.
8	(Chen & Liu, 2021); China	Cross-sectional N = 937	Distance to Park	General mental health (K6 scale)	Participants' psychological problem was sensitive to the distance from their residence to the nearest park.
9	(Cheng et al., 2021); China	Ecological N = 1305	Normalized difference vegetation index (NDVI) of Urban park	Happiness	Higher greenness in the park led to higher happiness among participants.
10	(Corley et al., 2021); Scotland	Cross-sectional N = 171	Gardening; and Garden usage frequency	General mental health; COVID-Anxiety; Sleep Quality (1-item Pittsburgh Sleep Quality Index)	Gardening was not associated with general mental health, anxiety, and sleep quality. Increased garden usage was associated with better general mental health and sleep but not with COVID-19 anxiety.
11	(Dzhambov et al., 2021); Bulgaria	Cross-sectional N = 3228	Plants at home; Green view from window; Presence of a domestic garden; Perceived neighborhood greenery	Anxiety (GAD-7); Depression (PHQ-9)	Having additional plants at home and the presence of a garden was not associated with anxiety and depression. Having a green view from the window and perceived neighborhood greenery was associated with both anxiety and depression.
12	(Friedman et al., 2022); UK	Cross-sectional N = 376	Nature connection	Emotional problem	Changes in nature connection positively influenced emotional problems among children.
13	(Garrido-Cumbrera et al., 2021); Spain, UK, Ireland	Cross-sectional N = 3109	Nature sound	Mental Well-being (WHO-5)	Improved nature sound during lockdown promotes better mental well-being.
14	(Gola et al., 2021); Italy	Cross-sectional N = 77	Green Space in Healthcare facility; Public green space (shared garden, public park); Private green space (private garden, balcony/terrace)	Profile of Mood States (POMS) (34 Items)	Nearby green spaces in healthcare facilities improve the psychophysical well-being of hospital staff.
15	(Groot et al., 2022); Denmark	Cohort N = 7445	Access to outdoor greenspace	Mental well-being (7-item); Loneliness (1-item)	No access to outdoor spaces was associated with higher odds of low mental well-being and higher loneliness.
16	(Hansmann et al., 2021); Switzerland	Cross-sectional N = 5932	Access to outdoor greenspace	Mental well-being (4-item)	Having a livable private outdoor space (e.g., gardens) reduces subjective psychological strain and improves well-being.
17	(Heo et al., 2021); South Korea	Cross-sectional N = 322	Changes in frequency of visits to greenspace during the pandemic compared to pre-pandemic; Enhanced Vegetation Index (EVI)	Depression (PHQ-9); Anxiety (GAD-2)	Decreased visits to greenspace were associated with higher odds of depression but not with anxiety. Higher EVI greenness was not associated with depression and anxiety.
18	(Hubbard et al., 2021); Scotland	Cross-sectional N = 2969	Access to a livable outdoor space (garden, balcony, patio, etc.); Frequency of visit to greenspace; Time spent in greenspace	General mental health (PHQ-4)	Having no access to a private space was associated with worse mental health scores. The frequency of nature visits was associated with general mental health. Time spent in greenspace was not associated with general mental health.
19	(Huerta & Utomo, 2021); Mexico	Cross-sectional N = 1954	Quality of urban greenspace (UGS); Frequency of UGS use during and pre-COVID-19; Distance to the nearest green space	Mental Well-being Scale (WEMWS);	Longer walking distance to greenspace was associated with lower well-being. Higher quality of greenspace was associated with higher well-being. Longer walking distance to greenspace and higher quality of greenspace was not associated with the change in well-being.
20	(Jackson et al., 2021b); USA	Cross-sectional N = 624	Frequency of nature-based activities” confined to more natural settings; Nature experiences	Mental Well-being change (WHO-5)	More frequent participation in nature-based activities pre-COVID was not associated with well-being. Continued participation in nature-based activities was associated with increased well-being.
21	(Jackson et al., 2021a); USA	Cross-sectional N = 624	Nature experience activities focused on activities occurring in more natural settings; Connectedness to nature (six items).	Subjective well-being (SWB) (4-item)	Participation in nature-based activities was associated with higher mental well-being. Connection to nature was not associated with mental well-being.
22	(Jato-Espino et al., 2022); Spain	Cross-sectional N = 9883	Green area (150m, 300m, 500m distance); Urban park (150m, 300m, 500m distance); Natural area-300m distance; Vegetated area-500m distance	Stress; Mood	The green area at 150-m and 300-m buffer distances were associated with lowering stress. Urban parks at 500-m distances were negatively associated with mood.

23	(Kontsevaya et al., 2021); Russia	Cross-sectional N = 2432	Access to greenspace	Sleep quality (3-item)	Having access to greenspace had no association with sleep quality.
24	(Kou et al., 2021); China	Participatory action research (PAR) N = 1154	Community gardening	General Mental health (Self-reported)	Community gardens had significant positive influences on the mental health of residents.
25	(Lades et al., 2020); Ireland	Cross-sectional N = 604	Gardening	Positive affect (3-item), Negative affect (3-item)	Gardening was associated with the largest positive affects.
26	(Larson et al., 2022); USA	Cross-sectional N = 1280	Area (km2) of local park/10000 residents; Area (km2) of national park/10000 residents; NDVI; Reducing park usage	Emotional problem (5-item)	Area of state or national park per 10000 residents and reducing park usage were associated with lowering emotional distress. High greenness and area of local park per 10000 residents were not associated with emotional distress.
27	(Lee et al., 2021); South Korea	Cross-sectional N = 1196	Frequency of visits to the forest site; Time spent at the forest site; Walking time distance to the forest site	Mental Well-being (PWI-SF)	Time spent at greenspace (forest site) was associated with improved well-being. Frequency of visits to greenspace and distance to greenspace not associated with well-being.
28	(Lehberger et al., 2021); Germany	Cross-sectional N = 495	Presence of a garden; Time spent in gardening weekly; Time spent in the public greens	Mental Well-being (WEMWBS); Life satisfaction (1 item)	Having a garden was not associated with well-being and life satisfaction. Spending more time in greenspace was associated with higher well-being but not with life satisfaction.
29	(Lenaerts et al., 2021); Belgium	Cross-sectional N = 11352	Frequency of nature visit	General Mental health (self-reported 6-items)	More frequent visit to nature was associated with improved general mental health.
30	(LÃµhmus et al., 2021); Sweden	Cross-sectional N = 2060	NDVI within 50m, 100m, 300m, and 500m buffer distance; Frequency of nature visits	Mental Well-being (RAND-36); Anxiety (SCL90); Depression (SCL90); Stress (PSS)	Higher residential greenness was associated with better mental health and lower stress but not with anxiety and depression. Visiting nature was often associated with better mental well-being, lower stress, and lower depression but not with anxiety.
31	(Marques et al., 2021); Brazil	Cross-sectional N = 173	Frequency of visit to parks and beach; Green view from window; Plants at home; Presence of a garden; Distance to greenspace	General mental health (DASS21)	Having a garden, a greener view, and visiting nature were often associated with less mental health problems. Having more plants at home and a greater distance to greenspace was not associated with the mental health problem.
32	(Mead et al., 2021); UK	Cross-sectional N = 138	Connectedness to nature	Mental Well-being (WEMWBS)	Higher nature connectedness was not associated with well-being.
33	(Millán-Jiménez et al., 2021); Spain	Cross-sectional N = 188	Green view from window; Presence of outdoor space (terrace, balcony, garden area with shared pool, garden area, patio)	Depression symptoms; Anxiety; Irritability or bad moods; Happiness; Sleep problem (Insomnia),	Participants who enjoyed open spaces (balcony, garden, terrace) found a sense of mental peace.
34	(Mintz et al., 2021); Israel	Cross-sectional N = 776	Nature near home; Green view from window; Nature connection	Stress (STAI); Positive Affect, Negative Affect (PANAS); Happiness (1-item);	Nature near home and green view from the window were associated with the largest positive affects and lowering stress but not with happiness. Nature connection was not associated with positive affect, stress, and happiness.
35	(Okely et al., 2021); 14 countries	Longitudinal N = 948	Presence of a livable outdoor greenspace (e.g., balcony, yard)	Sleep duration	Having access to outdoor nature was not associated with sleep duration.
36	(Olszewska-Guizzo et al., 2021); Singapore	Longitudinal N = 25	Frequency of visits to nature areas; Time spent in nature areas	Depression (BDI- II); Profile of Mood Scale (POMS)	Frequent visits and time spent in nature were not associated with depression and mood.
37	(Oswald et al., 2021); Australia	Cross-sectional N = 1004	Presence of a livable outdoor greenspace (e.g., balcony, yard); Walking distance of a greenspace/blue space; Perceived neighborhood greenery; Time spent in nature	General mental health (MHC-SF and K10)	Having a garden/balcony/yard and living >300m from a greenspace was not associated with mental health problems. Higher perceived greener neighborhoods and time spent in nature were associated with less mental health problems.
38	(Pearson et al., 2021); USA	Cross-sectional N = 56	Changed usage of greenspace (parks/trails/sidewalks, botanical gardens, backyard/porch/balcony)	Stress (PSS-10)	Increased usage of the backyard/porch was associated with lower stress. Decreased usage of parks/trails was significantly associated with higher stress.
39	(Pérez-Urrestarazu et al., 2021); 46 Countries	Cross-sectional N = 4205	Frequency of visits to greenspace; Plants at home	Mental Well-being (bespoke items)	Plants at home was associated with better mental well-being. Frequent visit to nature was not associated with mental well-being.
40	(Poortinga et al., 2021); UK	Longitudinal N = 5566	Distance to nearest greenspace; Access to private garden	Mental Well-being (SF36 items)	Longer walking distance was associated with lower mental well-being. Access to a garden was associated with higher mental well-being.
41	(Sarai Pouso et al., 2021); 77 Countries	Cross-sectional N = 5218	Green view from window; Presence of outdoor space availability (e.g., garden)	Depression (PHQ-2); Anxiety (GAD-2)	Having a nature view and access to garden/balcony/patio were associated with lower odds of depression and anxiety.
42	(Ribeiro et al., 2021); Portugal, Spain	Cross-sectional N = 1638	Indoor plants; Balcony plants; Presence of home garden; Green view from window; Community private greenspace; Public natural space	General mental health (GHQ12); Stress (1-item)	Having indoor plants, greener views and public natural spaces were associated with lower stress. Having a greener view was associated with less mental health problems. Having balcony plants, home garden, private community greenspace were not associated with stress and general mental health problems.
43	(Robinson et al., 2021); 14 Countries	Ecological N = 1184	NDVI at 50-m, 100-m, 250-m, 500-m; Distance to green space	Mental Well-being (WEMWBS); Stress	Higher greenness and distance to greenspace (< 250m) was not associated with well-being and stress.

44	(Samuelsson et al., 2021); Sweden	Cross-sectional N = 684	Distance to greenspace (natural land cover) from home and physical and visual accessibility; Frequency of visit to this natural land cover	Subjective well-being (1-item)	Abstaining from visiting natural land cover places (e.g., forests, water) was associated with a negative influence on mental well-being.
45	(Samus et al., 2022); New Zealand, Germany	Cross-sectional N = 261	Time spent in nature spaces, Garden use, Nature connection	Positive and Negative Affect (PANAS); Depression (CES-D)	Time spent in nature spaces and nature connection were associated with the largest positive affects. Time spent in nature spaces, garden use, and nature connection were not associated with depression.
46	(Sansal et al., 2021), Turkey	Cross-sectional N = 79	Time spent in outdoors space	Depression, Anxiety, Stress (DASS-42); Sleep	Time spent in outdoor nature during lockdown was associated with improved sleep quality and emotional well-being.
47	(Sia et al., 2022), Singapore	Cross-sectional N = 5661	Time spent in gardening weekly	Mental resilience (SYRSS-10)	Length of weekly gardening time was positively associated with mental resilience.
48	(Soga et al., 2020); Japan	Cross-sectional N = 3000	NDVI at 250m; Green view from window; Frequency to visit greenspace	Life Satisfaction (LSI-A); Happiness (SHS); Loneliness (UCLA Loneliness); General mental health (GHQ-12)	Having a green view and more frequent visits to greenspace were associated with better mental health, higher life satisfaction, more happiness, and lower loneliness. Higher greenness was not associated with mental health, life satisfaction, happiness, and loneliness.
49	(Spano et al., 2021); Italy	Cross-sectional N = 3886	Plants at home; Green view from window, Accessibility to private green space	Anxiety; Sleep disturbance	Better access to garden, greener view, and plants at home were associated with lower sleep problems. Better access to garden, and greener view were associated with lower anxiety. Plants at home was not associated with anxiety.
50	(Sundara Keeren et al., 2021); Malaysia	Cross-sectional N = 30	Nature exercise; Nature therapy	Depression, Anxiety, Stress (DASS-42)	Participation in nature therapy and nature exercise program were associated with a reduction in stress, anxiety, and depression.
51	(Theodorou et al., 2021); Italy	Cross-sectional N = 303	Gardening activities	General mental health (K9)	Gardening (vs. no gardening) was associated with less mental health problems.
52	(Tomasso et al., 2021); USA	Cross-sectional N = 529	Connectedness to nature (INS scale); Nature deprivation perceived	Mental Well-being (flourishing HFI)	Connectedness to nature and perceived nature deprivation were not associated with lower well-being.
53	(Vos et al., 2022); Belgium	Cohort N = 766	Greenspace area at 50 m, 100 m, 300 m, 500 m, and 1000 m	Stress	Greenspace area at multiple buffer distances was associated with lowering stress.
54	(Wortzel et al., 2021); USA	Cohort N = 2089	Greenspace at 0-m, 100-m, 250-m, 500-m, 100-m	Anxiety (GAD-7); Depression (PHQ-2); COVID-19 stress	Greenspace at multiple buffer distances was associated with lowering depression but not with stress and anxiety.
55	(Xie et al., 2020); China	Cross-sectional N = 386	Time spent in greenspace; Frequency of visits to greenspace	General mental health (1 item)	Time spent in greenspace was associated with less mental health problems. Frequent visit to nature was not associated with the mental health problem.
56	(Yao et al., 2022); China	Ecological N = Urban residents of 296 cities in China	Area of parks and green spaces (Parkland)	Mental stress index	Area of parks and greenspaces was associated with lowering stress.
57	(Young et al., 2021); USA	Longitudinal N = 20012	Time spent in outdoor nature	Anxiety (GAD-2); Depression (PHQ-2)	Spending less time in outdoor nature was associated with higher depression and anxiety.
58	(Zhang et al., 2022); China	Cross-sectional N = 900	Tree canopy coverage (TCC)	General mental health (GHQ12)	Higher tree cover was associated with lower odds of mental health problems.
59	(Zhuo & Zacharias, 2021); China	Cross-sectional N = 284	Presence of livable outdoor space (yard or terrace, balcony)	Mental well-being (6-item)	Having access to a balcony was negatively associated to mental well-being.

Notes: PHQ: Patient Health Questionnaire; CES-D: Center for Epidemiological Studies-Depression; GAD-7: Generalized Anxiety Disorder-7; DASS: Depression, Anxiety, Stress Scales; PSS: Perceived Stress Scale-10; POMS: Profile of Mood States; WEMWS: Warwick–Edinburgh Mental Wellbeing Scale; PWI-SF: Psychosocial Well-Being Index; SCL: Symptom Checklist; SWE: Subjective Well-Being; STAI: State-Trait Anxiety Inventory; PANAS: The Positive and Negative Affect Schedule; BDI: Beck Depression Inventory; MHC: Mental Health Continuum; GHQ: General Health Questionnaire, LSI: Life Satisfaction Index; HFI: Harvard Flourishing Index; UCLA: University of California, Los Angeles.

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