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**Natural Environments, Psychosocial Health, and Health Behaviors during COVID-19 –
A Scoping Review.**

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nature*

Abstract

The COVID-19 outbreak has led to major restrictions globally, affecting people's psychosocial health and their health behaviors. Thus, the purpose of this scoping review was to summarize the available research regarding the nature-health-association in the COVID-19 context. Keywords related to natural environments and COVID-19 were combined to conduct a systematic online search in six major databases. Eligibility criteria were a) published since 2020 with data collected in the COVID-19 context b) peer-reviewed, c) original empirical data collected on human participants, d) investigated the association between natural environments and psychosocial health or health behavior, and e) English, German, or Scandinavian language. Out of 8,568 articles being obtained, we identified 82 relevant articles representing 80 unique studies. Most studies focused on adults in the general population and were predominantly conducted in the USA and Europe. Overall, the findings tentatively indicate that nature mitigates the impact of COVID-19 on psychological health and physical activity. Through thematic analysis of the extracted data, three primary themes were identified: 1) type of nature assessed, 2) psychosocial health and health behaviors investigated, and 3) heterogeneity in the nature-health relationship. Research gaps in the COVID-19 context were identified regarding I) nature characteristics that promote psychosocial health and health behaviors, II) investigations of digital and virtual nature, III) psychological constructs relating to mental health promotion, IV) health behaviors other than physical activity, V) underlying mechanisms regarding heterogeneity in the nature-health relationship based on human, nature, and geographic characteristics, and VI) research focusing on vulnerable groups. Overall, natural environments demonstrate considerable potential in buffering the impact of stressful events on a population level on mental health. However, future research is warranted to fill the mentioned research gaps and to examine the long-term effects of nature exposure during COVID-19.

Introduction

The COVID-19 pandemic, declared on 11 March 2020, had a major impact on society globally. As of September 2021, the estimated death toll attributed to the virus is almost 5 million people (Dong et al., 2020). To mitigate the spread of the virus, many governments introduced containment measures such as physical distancing, suspension of social events, and restricted mobility, which resulted in significant social and economic consequences across different sectors (Nicola et al., 2020). Although more than 6 billion people have been vaccinated against COVID-19 as of September 2021 (Dong et al., 2020), many places continue to have containment measures, such as Australia (Australian Government, n.d.).

The pandemic challenges individuals' health and well-being (Brazendale et al., 2017). For instance, across the world, psychological health and well-being have declined across the pediatric and adult population, while psychiatric symptoms and feelings of loneliness have increased due to physical distancing (Lee et al., 2020; Loades et al., 2020; Vindegaard & Benros, 2020; Wunsch et al., 2021; Xiong et al., 2020). In addition, the restrictions related to COVID-19 challenge individual health behaviors that are typically embedded into structures related to work or school (Brazendale et al., 2017) as the context-dependent boundaries were longer available to many due to teleworking and home education. For example, several studies have identified a decline in physical activity and an increase in sedentary behavior (Stockwell et al., 2021), adverse changes in eating behavior (Bhutani et al., 2021; Herle et al., 2021; Robinson, Boyland, et al., 2021), as well as a substantial risk of problematic alcohol use and overuse of online gaming (Xu et al., 2021).

These detrimental developments provide an impetus to identify factors beyond a biomedical model that empower the general and especially vulnerable populations, defined as populations that are susceptible to psychological, physical, or social harm, health problems, or neglect (Phillips, 1992; Rogers, 1997) to maintain and promote their psychosocial health and health behaviors during the COVID-19 pandemic (Holmes et al., 2020; Kola et al., 2021).

Prior to the COVID-19 outbreak, numerous studies, including reviews, have demonstrated that exposure and access to nature in its various forms, including (urban) green space, blue space such as rivers, private green space, such as gardens, or visual nature experiences are related to improved mental health and well-being and a reduced risk for psychiatric disorders (Bratman et al., 2019; De Bell et al.,

2020; Engemann et al., 2019; Tost et al., 2019; White et al., 2020; WHO, 2016). In addition, several studies support the concept that access and exposure to natural environments has the potential to promote physical activity (Remme et al., 2021), while interacting with nature, e.g. via gardening, can promote beneficial dietary behaviors (Beavers et al., 2020; Davis et al., 2011).

The complex underlying mechanisms linking nature to health, well-being, and health behaviors are not entirely elucidated and require further investigation (Kuo, 2015). However, Hartig et al. (2014) suggest that nature contact leads to enhanced health and well-being via better air quality, increased physical activity, social contacts, and stress reduction. These mediators have also been confirmed in a recent systematic review (Zhang et al., 2021). As a result, nature exposure, including access to biodiversity and recreational activities in nature, are recommended to strengthen psychological resilience (Aerts et al., 2021).

The COVID-19 pandemic has influenced human behavior in and use of green space and natural environments. Depending on the containment measure in place, some people have interacted less with nature and others more (Burnett et al., 2021a; Geng et al., 2021; Ugolini et al., 2021). Consequently, it is crucial to obtain information about the role of natural environments regarding psychosocial health and health behaviors during this pandemic. Thus, this review aimed to identify the available evidence related to the role of natural environments regarding psychosocial health and health behaviors across different populations published since the outbreak of the COVID-19 pandemic. The main question was: What do we know about the existing literature regarding the relationship between natural environments and psychosocial health as well as health-related behaviors in the COVID-19 context? Specifically, we were investigating: a) Which types of nature were investigated in the context of the COVID-19 pandemic?, and b) Which psychosocial health outcomes and health behaviors in relation to nature were investigated during the COVID-19 pandemic?

Methods

We used a structured scoping review and thematic analysis approach to explore our research question. The reporting follows the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Reviews (Prisma-ScR; Tricco et al., 2018). Scoping reviews aim to map

key concepts, evidence types, and research gaps in a research field based on a systematic search and knowledge synthesis (Colquhoun et al., 2014). We followed the established five-step process of Arksey and O'Malley (2005), including I) identification of the research question, II) identification of relevant studies, III) study selection, IV) data charting, and V) result summary and report.

First, the research group met several times to discuss the research question (step I), which was guided by the PCC mnemonic (*Population*: Humans, *Concepts*: Natural environment, and psychosocial health or health-related behavior, and *Context*: COVID-19) (Peters et al., 2020). The team also agreed on definitions and the breadth of key terms in our research question (natural environment, psychosocial health, and health-related behaviors). We purposely applied a broad understanding and definition of the concepts to allow a comprehensive search and knowledge map. We defined natural environments as outdoor areas with physical features and processes of non-human origin (Hartig et al., 2014). During the screening process, we identified multiple articles that included activities bound to take place in nature. Thus, we expanded our inclusion of articles that focused on nature-based activities. Following the example of Wolsko et al. (2019), we included nature-dependent activities (e.g. skiing, swimming, kayaking), nature consumption-related activities (e.g. fishing, hunting, gardening), and motorized activities in nature (e.g. quad bikes, motor boats) in our definition. Psychosocial outcomes were defined as any psychological or social aspects that are influenced by the environment and biological aspects and their interrelationship with human behavior (Vizzotto et al., 2013), such as well-being, mood, quality of life, self-esteem, or cognition. Health behavior was defined as any behavior associated with health benefits (e.g. physical activity, eating behavior).

Next, we identified relevant databases, and defined search terms as well as inclusion and exclusion criteria (step II). The latter was executed in an iterative process based on internal discussions and preliminary online searches to refine the research question and review execution. Search terms were defined based on the author's topic-related knowledge. Additional search terms were identified in the titles, abstracts, and keywords of relevant articles in a preliminary search. Following the preliminary search, a comprehensive online search was conducted in the databases Web of Science, Scopus, PubMed, Embase, CINAHL, and Greenfile on April 14, 2021, and updated on July 7, 2021 to include the latest literature in this scope. The search strategy was based on two strings, combining subject

headings (MeSH terms) and keywords related to natural environments (e.g. green space, park, digital nature) and COVID-19 (e.g. Sars-Cov-2, pandemic, lockdown). The exhaustive search strategy for this study is provided in the *supplement S1*. Studies were included if they a) were published since 2020, b) included data collected since the outbreak of COVID-19, c) were accepted or published in a peer-reviewed journal, d) presented original empirical data collected on human participants, independent of the underpinning methodological approach (quantitative or qualitative), e) assessed the association between natural environments and psychosocial health or health behavior, and f) were written in English, German, or Scandinavian. A protocol presenting the project's objective and planned procedures was registered via the Open Science Framework platform (OSF) on June 6th, 2021 (available online: <https://osf.io/ad2sx/>).

For study selection (step III), all retrieved records were imported to and processed in Endnote Desktop reference management software (version X9.3.3). Following the removal of the duplicates, both the first and second author independently scanned titles first, then abstracts, and finally full-texts (see *Figure 1*). After consensus the first and second author (C.N. and E.P.) reached consensus in each step, both authors extracted and inputted data from the final articles collection in a Microsoft Word spreadsheet. If no consensus could be reached, the third author (T.M.) was consulted. After piloting the data extraction, we decided to systematically extract the following information from each study (step IV): Authors' names, year of publication, study location (country), sample characteristics (size, age, gender, ethnicity), study design, methodological approach, data collection methodology, study objective, operationalization and measures of the used concepts nature and health/ health behavior, and the main findings.

To prepare the extracted data for the report (step V), we utilized a thematic analysis approach to summarize our findings and identify recurring themes. After we had extracted the data, one researcher (C.N.) imported the table into the program MAXQDA Analytics Pro (version 20.4.1). Following the guidelines proposed by Braun and Clarke (2006), we applied initial coding on each article charted in the table. Before conducting the thematic analysis, the first author (C.N.) piloted the coding and categorization process and discussed the applied procedures with the second author (E.P.). Then, the authors decided to follow a deductive and inductive process. Based on our research question, two main

categories were established: a) Type of nature assessed, and b) Health outcomes and health behavior assessed. Within these two domains, sub-categories were developed based on a data-driven approach. Codes that did not fit in either category were re-visited to develop a more representative code system during the coding process. The initial coding was conducted based on the column nature operationalization, measurement, and main findings. If required for a better understanding, additional information was obtained from the article. The first author (C.N.) organized the initial codes into categories in a systematic, repetitive process. As more articles were coded, they were mapped into previously identified categories, and new categories were established as new themes were discovered. Topic categories were not mutually exclusive, and an article's content could be mapped into multiple categories. The lead author regularly revisited and reviewed the categorization and memos from previous coding rounds to ensure appropriate categorization with newly discovered themes during the coding and categorisation process. Furthermore, the coding and categorization process was discussed with all authors, and the categories were adapted until all authors agreed.

As we applied the coding process to synthesize the evidence, we report the number of codes obtained for each primary category and major sub-categories in the result section. A coding protocol that accompanied the coding process as well as the MAXQDA-file containing the final codes can be found in the data repository: <https://osf.io/ad2sx/>.

Results

Descriptive study characteristics

The database search resulted in a total of 8,568 records. Before we started the screening process, we removed 4,283 duplicates. Thus, 4,285 search results were screened based on their titles, resulting in 82 articles representing 80 studies included in our review. A flow diagram of the screening process is presented in *Figure 1*. Most studies were quantitative ($n = 58$), cross-sectional ($n = 67$), and observational ($n = 76$). Data was mostly collected via online surveys ($n = 61$) from the general population ($n = 56$). Most studies only included adults ($n = 62$), the most common sample sizes were 101-1000 participants ($n = 32$) and 1001-10,000 participants ($n = 30$). The methodological characteristics of the

articles included are summarized in *Table 1*. Most studies were conducted in the USA ($n = 12$), Italy ($n = 11$), Spain ($n = 9$), and the UK ($n = 9$). A map displaying all countries that studies were conducted in is displayed in *Figure 2*.

Figure 1. Flow diagram of the screening process

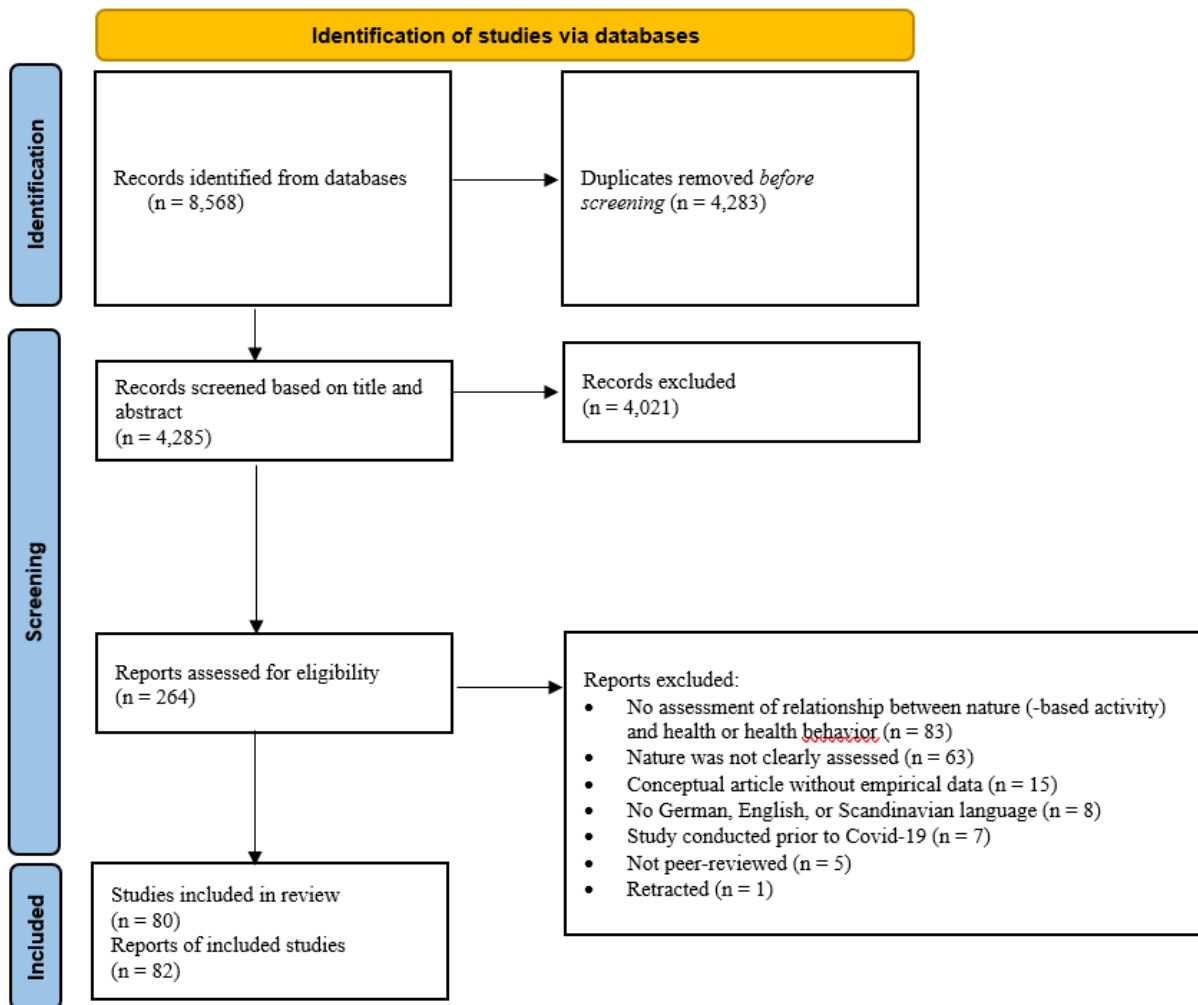
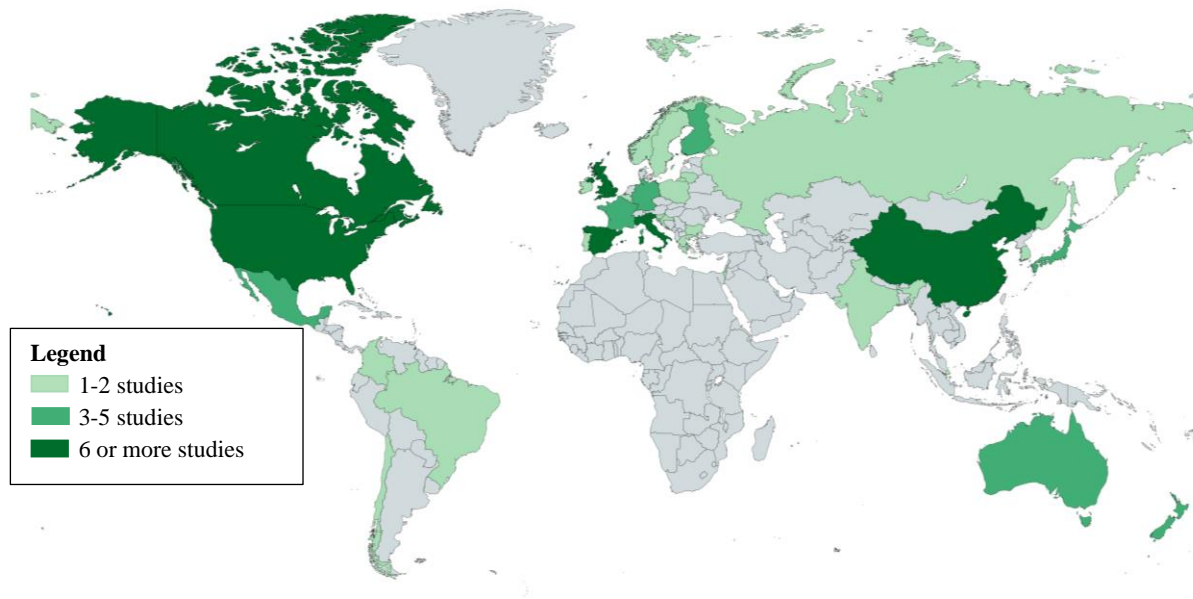


Table 1. Methodological characteristics of the included articles (N = 82, 80 studies)

<i>Characteristics</i>	<i>Categories</i>	<i>n</i>
Methodological approach	Quantitative	58
	Qualitative	10
	Mixed-Methods	12
Study design	Cross-sectional	67
	Longitudinal	9
	Intensive longitudinal	1
	Case-study	5
Study type	Observational	76
	Experimental	5
	Participatory action research	1
Data collection methodology	Online survey	61
	Other survey forms	5
	Objective / device-based	12
	Social media/fitness app analysis	6
	Qualitative interviews	6
	Ethnographic approaches	3
	Photography	3
	Other	3
Nature assessment	Self-report	60
	Objective	17
	Nature visitation	4
	Digital nature exposure	4
Study population / sample	General population	56
	University students	5
	Adult employees	1
	Park and forest visitors	5
	Recreational fishers	1
	Health care workers	1
	COVID-19 hospital staff and patients	1
	COVID-19 risk group	1
	People with obesity	1
	People with tinnitus	1
	Soundscape experts	1
	Webcam travelers	1
	Fitness app recordings (Strava)	2
	Social media posts	3
Sample age	Children	8
	Adolescents	14
	Adults	62
	Older adults	55
Sample size	≤ 10	2
	11-100	8
	101-1,000	32
	1,001-10,000	30
	≥ 10,000	3

Please note: Some studies applied multiple study designs, data collection methodologies, and nature assessments and included multiple age groups. Thus it is possible that the sum of the categories exceeds the number of studies and included articles. The sample size category does not include sample information about social media (e.g., number of posts). Children were defined as participants up to nine years, and adolescents from ten 10 to 17 years (Sacks, 2003).

Figure 2. The frequency of studies based on the geographical location of the sample.



Please note: In large-scale multi-country studies, we only included countries with 100 or more responses ($n = 3$).

Themes identified

We identified three primary categories in our analyses: 1) Assessing nature, 2) Health outcomes and health behaviors investigated, and 3) Heterogeneity regarding the association between nature and health outcomes and health behavior. A summary of the studies included is presented in *Table 2*, and a table with a detailed description can be found in *supplement S2*.

Nature investigated during COVID-19

From a geographical point of view, both public and private nature were investigated during COVID-19. Public nature was the domain that received the greatest interest ($n = 47$ codes), specifically parks ($n = 14$ codes), and urban natural areas ($n = 12$ codes). Private nature was less investigated ($n = 19$ codes) and concentrated on gardens ($n = 7$ codes) and garden access ($n = 6$ codes).

Regarding the characteristics of nature, most studies looked at nature-based activities ($n = 15$ codes), specifically gardening ($n = 8$ codes). The second most frequent category was green space and vegetation ($n = 13$ codes), followed by views on nature from the window ($n = 8$ codes), general nature ($n = 7$ codes), and any nature type that was mentioned by the participant ($n = 7$ codes). Less investigated were digital

nature in forms of webcam travel, videos, and virtual nature experiences ($n = 5$ codes), blue space ($n = 4$ codes), and nature sounds ($n = 3$ codes).

Health outcomes and health behaviors in relation to nature during COVID-19

The large majority of health outcomes and health behaviors were positively related to nature ($n = 175$ codes), with only a few studies reporting null results or a negative association between nature and psychosocial health or health behaviors ($n = 24$ codes).

The most extensive category investigated in relation to nature was psychosocial health ($n = 152$ codes), followed by health behaviors ($n = 47$ codes).

Within psychosocial health, the majority of studies focused on psychological health ($N = 126$ codes). Most of interest were well-being ($n = 47$ codes), followed by stress ($n = 31$ codes), mood and emotions ($n = 17$ codes), and depression and anxiety ($n = 17$ codes). Less frequently investigated were coping ($n = 5$) and recovery ($n = 4$). One reoccurring topic specific to the COVID-19 context was the perceived break from pandemic ($n = 4$ codes), with participants indicating that nature allowed them feelings of escape from the ubiquitous pandemic life situation.

Some articles reported on social health and nature during COVID-19 ($n = 26$ codes). Social health was mostly investigated regarding social connections and interactions ($n = 11$ codes) and general social health ($n = 7$ codes). In addition, time for family ($n = 5$ codes) and community health benefits of nature ($n = 3$ codes) were themes that the research covered.

Regarding *health behaviors*, physical activity behavior was most exhaustively examined in different variations ($n = 33$ codes), including walking, exercising, doing sports, general physical activity, and meeting the physical activity guidelines. Other behaviors of the 24-hour movement cycle, such as sedentary behavior ($n = 2$ codes), sleep ($n = 2$ codes), and play behavior of children ($n = 4$) and eating behaviors ($n = 3$), were rarely investigated.

Heterogeneity in the nature-health association during the COVID-19 pandemic

The associations between nature and health varied based on population characteristics ($n = 22$ codes), nature characteristics ($n = 8$ codes), and characteristics of the geographic regions ($n = 6$ codes).

Most common variations based on the populations' features ($n = 9$ codes) were related to age and gender. In addition, heterogeneity emerged regarding garden and outside access ($N = 5$ codes). Less investigated were other human characteristics, such as ethnicity ($n = 1$ code) and characteristics more specific to the COVID-19 pandemic, e.g., being in a high-risk group ($n = 1$), doing home office ($n = 1$), and social interaction during the pandemic ($n = 1$).

Heterogeneity was less frequently examined regarding characteristics of nature, including variations based on nature types ($n = 4$ codes), such as forest or park type, and nature quality ($n = 2$ codes).

Regarding geographic heterogeneity, variations were primarily investigated between countries ($n = 3$ codes).

Table 2. Characteristics of the included studies

Author (year), country	Study population (N)	Objective	Nature type or nature-based activity	Health outcome or health behavior	Summary of the main findings
Amerio et al. (2020), Italy	University students (8177)	Investigate associations between apartment architectural parameters and mental health	Green window view	Depressive symptoms	Green window view was unrelated to depressive symptoms.
Astell-Burt and Feng (2021b), Australia	Adults and older adults (2697)	Investigate associations between health-related green and blue space benefits and sociodemographic characteristics	Green space and blue space	Health-related benefits of nature visits	About half of the participants reported mental health benefits of green or blue space visits. About one-quarter of the participants reported that green or blue space visits promoted social reconnection with the neighbors and more exercise/walking in green or blue space since the onset of COVID-19. Perceived benefits varied by gender, age group, education, working situation, and nature relatedness scores.
Barron and Emmett (2020), Ireland	Children and adolescents (1467)	Identify the impact of COVID-19 on children's and adolescent's play and friendship groups	Garden	Play	Back gardens were turned into multifunctional spaces serving, amongst others, as playground, socializing space, as well as sports pitch and exercise space. Children without a back garden were seriously distracted to play and socialize outdoors, which especially affected children living in appartements.
Berdejo-Espinola et al. (2021), Australia	Brisbane adults and older adults (1002)	Investigate associations between changes people's perception of green space benefits and frequency in time spent in urban green space	Urban green and blue space	Reasons for visiting urban green and blue space Psychological well-being benefits	A majority emphasized improvement of personal well-being through visiting urban green and blue space through stress, anxiety, and depression reduction. Most participants indicated an increase in the importance of the psychological benefits obtained from urban green and blue space.
Beukes et al. (2021), Canada and USA	Adults and older adults with tinnitus (1522)	Investigate which resources individuals utilized to cope during the pandemic	Nature	Coping resources	Gardening was reported as support activity for coping.
Bhalla et al. (2021), India	Adult employees (9)	Investigate if spiritual tourism provides psychotherapeutic healing during COVID-19	Nature-based tourism	Mental health	Participants were looking forward to visiting various types of nature-based places to recover from the negative psychological effects of COVID-19 and thus improve mental health and well-being.
Bourion-Bedes et al. (2021b), France	University students (3764)	Investigate perceived stress levels of students and associated factors during COVID-19	Garden	Perceived stress	Compared to students with a private garden, students with a private balcony, courtyard or terrace and students without access to outside space had a higher probability of high perceived stress levels, whereas there was no difference compared to students with a courtyard or garden for collective use.

Bourion-Bedes et al. (2021a), France	University students (3936)	Investigate factors associated with anxiety during COVID-19	Garden	Anxiety	Compared to students with a private garden, students without access to outside space had a higher probability of moderate to severe anxiety. No differences compared to a private balcony, courtyard or terrace or a courtyard or garden for collective use was observed.
Browning et al. (2021), USA	University students (2534)	Investigate psychological impact of COVID-19 and associated factors	The outdoors	Psychological impact	Students spending two or more hours outdoors were less likely to be at risk or higher than average levels of emotional distress and worry time.
Bu, Steptoe, et al. (2021), UK	Adults and older adults (55204)	Investigate associations between specific activities or time use and mental health and well-being during COVID-19	Garden	Depression Anxiety Life satisfaction	Gardening activity was associated with less depressive and anxiety symptoms and more life satisfaction.
Burnett et al. (2021b), UK	Adults and older adults (2252)	Investigated changed experience of green space and associations with socio-demographic characteristics.	Green space	Mental health Physical activity Social interactions	About two thirds of the respondents agreed that green spaces benefited their mental health more after movement restrictions were introduced. About half of the respondents agree that they missed social interactions in green space more, and about one third agreed that they had increased physical activity in green space during the COVID-19 lockdown. Agreement probability varied by gender, social grade, age group, and dog owners.
Chen and Liu (2021), China	Adults and older adults (937)	Investigate the importance of risk factors with regards to psychological distress	Park	Psychological distress	Out of 18 sociodemographic, environmental, health, and individual's perception predictors, distance to the nearest park was ranked as the fourth most important predictor from objective environmental measures.
Cheng et al. (2021), China	Geotagged posts on Sina Weibo (Chinese Twitter)	Investigate association between urban parks, their characteristics, and happiness before and during COVID-19	Urban parks	Happiness	Residents living within the service buffer zone of the park showed higher happiness than residents outside the service buffer zone. Vegetation was related to enhanced happiness during, but not prior to the pandemic. The strength of the association was stronger for high vegetation and varied by urban park type.
Constant et al. (2020), Scotland	Adults and older adults (4005)	Investigate factors associated with healthy and unhealthy lifestyle changes during COVID-19	Garden	Changes in health behaviors	Having a garden was related to a higher number of changes in unhealthy changes and unrelated to changes in healthy behaviors.
Corley et al. (2021), Scotland	Older adults (171)	Investigate associations between home garden usage and mental health during COVID-19	Garden	Emotional and mental health Anxiety about COVID-19 Sleep quality	More garden usage during compared to prior to the lockdown was associated with better emotional and mental health, sleep quality, and composite health, while it was unrelated to anxiety about COVID-19. Gardening and relaxing in the garden were unrelated to all health outcomes.

Cuerdo-Vilches et al. (2020), Spain	Adults and older adults (242)	Investigate aspects of space of personal home that participants like least and that are most comfortable	Nature	Comfort	Spaces open to the outside, including gardens, were, amongst others, most valued during the lockdown for comfort, and provided a meeting place at the social level.
Dushkova et al. (2021), Russia and Australia	Adults and older adults in Moscow and Perth (326)	Investigate perceptions, values, and use of urban green and blue space during COVID-19	Urban blue and green infrastructure	Personal well-being and perceived benefits of urban nature	In both cities, respondents rated nature contact similarly important for mental health. Nature similarly perceived as a place to relax and unwind. Benefits related to social interactions with other people and family were mentioned by about half of the respondents in Perth, but less so by respondents from Moscow.
Dzhambov et al. (2020), Bulgaria	University students (323)	Investigate associations between greenery and mental health	Indoor and outdoor greenery	Depression Anxiety	Exterior green view and neighborhood greenery were related to lower levels of depression and anxiety and a reduced risk for clinical levels of depression and anxiety. Houseplants were only related to less depressive symptoms and a reduced risk for clinical depression levels, but not anxiety. Having a garden was unrelated to all outcomes except for anxiety symptoms
Gola et al. (2021), Italy	Health care workers (77)	Investigate well-being benefits of nature for hospital staff based on one self-selected nature experience	Nature	Well-being	Hospital staff working both Covid- and non-Covid-areas decreased anxiety, depression, anger, fatigue, and confusion after the nature experience, and increased strength. The greatest benefits were obtained if the nature experience took place during or after the work shift. The hospital garden yielded the most benefits for strength, while there were no remarkable differences for the other subscales between the different nature typologies.
Greenwood-Hickman et al. (2021), USA	Older adults with obesity (25)	Investigate the impact of COVID-19 on older adult's well-being and identify coping strategies	Nature	Coping strategies	Many participants reported more gardening, tending to plants, or doing major yard improvement projects as coping strategies. Simultaneously, yard work had the additional benefit of physical activity and allowing contact with neighbors.
Grima et al. (2020), USA	Visitors of parks and natural areas (346)	Investigate how natural areas provide basic non-material basic needs of urban communities	Urban and peri-urban natural areas	Motives for visiting natural areas	Motives for visiting urban parks and natural areas included exercise, finding peace and quiet, and socializing.
Heo et al. (2021), South Korea	Adults and older adults (322)	Investigate associations between patterns of greenspace use and psychological symptoms	Green space Vegetation	Depression Anxiety Motives for visiting green space	Decreases in green space visits, frequency of pre-pandemic green space visits, and enhanced vegetation were unrelated to the risk of major depressive and generalized anxiety disorder. Regarding reasons for visiting green space, during the pandemic, respondents were more likely to visit green space for stress relief compared to pre-pandemic, whereas less people reported visiting green space for relaxation, social reasons, or exercise compared to pre-pandemic.

Herman and Drozda (2021), New Zealand and Poland	Parks users and posts of social media users (125)	Investigate the functioning of green infrastructure during COVID-19	Two parks in Wellington and Warsaw	General health and well-being, including health behaviors	Green space played a crucial role for health and well-being, physical activity, sports, and play, and social life during the pandemic.
Hino and Asami (2021a), Japan	Adults (18817)	Investigate associations between changes in step counts and the neighborhood environment	Park	Step counts	Shorter distance to the nearest park mitigated a decline in step counts for older women during the COVID-19 state of emergency, while in some weeks the association was also observed for younger women. No association was observed prior COVID-19 and no association was observed for males.
Howarth et al. (2021), Canada	Recreational fishers (789)	Investigate how the pandemic impacted recreational fishers	Fishing activity	Motivation for fishing during the pandemic	The majority of recreational fishers agreed that fishing improves their physical and mental well-being and that they go fishing to spend time with their family/kids.
Hubbard et al. (2021), Scotland	Older adolescents and adults (502)	Investigate if frequency and duration of green space visits are related to mental health during COVID-19 and moderate relationships between individual demographics, illness beliefs, and mental health	Public green and open space	Psychological distress	More frequent green space visits, but not duration were associated with more psychological distress. Frequency and duration of green space visits moderated the association between being in a high-risk group for COVID-19 and psychological distress, with more frequent visits and shorter visits in green space relating to higher psychological distress. For less frequent and shorter green space visits, people in the high-risk group for COVID-19 did not differ from those not in the high-risk group.
Huerta and Cafagna (2021), Mexico	Adults in Mexico City (16)	Investigate the association between participants' urban green space use and well-being	Urban green space	Well-being	Urban green space use served as a coping mechanism for COVID-19 related stress and isolation and brought positive emotions. Those not having access reported more stress and anxiety and a lack of physical activity. Disparities in use and benefits of urban green space emerged, including accessibility barriers and fear of violence for women.
Huerta and Utomo (2021), Mexico	Adults and older adults in Mexico City (1945)	Investigate associations between the frequency of urban green space use and subjective well-being pre- and during COVID-19	Urban green space	Subjective well-being	Frequent urban green space use was associated with subjective well-being pre- and during COVID-19, with the relationship being stronger during the pandemic. Urban green space quality was associated with better subjective well-being pre- and during COVID-19. Those who started or maintained urban green space visits during COVID-19 had higher odds of maintaining or increasing subjective well-being. Distance to urban green space was only related to subjective well-being pre-pandemic.
Humberstone (2021), New Zealand	Older adults (1)	Investigate nature-based recreation and its contribution to health and well-being	Green and blue space	Health and well-being	Being in the outdoors affords enormous emotional and spiritual benefits for older people.

Idoiaga Mondragon et al. (2021), Spain	Children and adolescents (250)	Investigate the impact of the COVID-19 lockdown on children's emotional response	Nature	Emotional response	Children missed the outdoors and contact with natural elements during the lockdown, which was reflected in a negative emotional response.
Jackson et al. (2021), USA	Adolescents (624)	Investigate associations between different types of outdoor activities and subjective well-being	Nature	Subjective well-being Mental health	Continued participation in nature-based activities mitigated a decline in subjective well-being during COVID-19. Children who increased participation in nature-based activities during COVID-19 had similar levels of subjective well-being as prior to COVID-19. The majority of children agreed that nature-based activities helped them dealing with COVID-19 related stress, which translated to better mental health.
Jarratt (2021), mostly UK	Webcam travelers (227)	Investigate connections to places and nature via webcam travels	Digital nature	Well-being	Most of the respondents visited nature-based places via webcams. Visiting places via webcam-travel resulted in an uplift in mood and positive emotions.
Jenkins et al. (2021), New Zealand	Adults and older adults (759)	Investigate if physical activity context (nature-based vs. non-nature based) moderates the association between physical activity and psychological well-being during the COVID-19 lockdown	Nature during physical activity	Psychological well-being Motivational quality	Both nature- and non-nature based physical activity were positively related to psychological well-being, with no moderation of the context.
Kolbe et al. (2021), USA	Patients and hospital staff in the COVID-19 recovery unit (24)	Investigate satisfaction and perceived benefit of a virtual reality tool during COVID-19	Digital nature	Satisfaction Perceived benefits	Patients were highly satisfied with the virtual experience with regards to helping to manage their pain and anxiety and hospital staff was highly satisfied with regards to helping to manage stress. Several benefits, including feelings of escape, enhanced alertness, relaxation, coping, feelings connected to others, and self-care were reported.
Kontsevaya et al. (2021), Russia	Adults and older adults (2432)	Investigate factors associated with physical activity and sleep changes during COVID-19	Green space	Physical activity Sleep habits and quality	Respondents with green space access were more likely to meet the physical activity and muscle-strengthening activity guidelines, while it was unrelated to pandemic-related changes in moderate, vigorous, and muscle-strengthening physical activity, walking, and not getting enough sleep.
Kou et al. (2021), China	Shanghai community gardeners, citizens and people outside the community (1154.)	Investigate the impact of community gardening on resident's daily life during COVID-19	Gardens	Mental health Social interactions Perceived benefits	Gardening activities allowed social interactions that can mitigate people's psychological stress during a major public health emergency and contributed to improved mental health and social cohesion and interactions for the entire community.
Lades et al. (2020), Ireland	Adults and older adults (604)	Investigate associations between daily activities and affective experiences	Garden	Emotional well-being	Gardening activity was related to enhanced positive affect, but not negative affect.
Larcher et al. (2021), Italy	Adults and older adults (3286)	Investigate public green area perception during the physical distancing period	Public green-area	Psychological and physical need for green space	About two thirds of the participants reported a pressing or recurring psychological or physical need to visit public green areas. The need varied by gender, age group, frequency of

					green space visits pre-pandemic, outside access, and having a garden.
Lee and Jeong (2021), UK	Social media posts in London	Investigate changes in noise sources of annoyance during COVID-19	Nature sounds	Noise complaints	Increases in complaints about bird noise from pre- to during lockdown were observed.
Lee et al. (2021), South Korea	Park visitors (1196)	Investigate associations between forest types and well-being	Forests	Perceived restorativeness Social-psychological stress Reasons for visiting forests during COVID-19	Perceived restorativeness of forests was negatively related to social-psychological distress. Perceived restorativeness varied by forest type, but not social-psychological distress. Healthy people tended to spend more time in the forest than the potential and high-risk stress group. The most common reason for visiting the forest was physical activity.
Lehberger et al. (2021), Germany	Adults and older adults (495)	Investigate associations between use of green space and well-being during COVID-19	Garden Public green space	Mental well-being Life satisfaction Meaning of green space during COVID-19	Results indicated that garden owners had greater life satisfaction and mental well-being than non-garden owners. Results indicated that not garden ownership itself, but rather variables related to garden ownership were the key to understanding the differences in self-reported well-being and life satisfaction, including less fear of job loss, higher income, more time in their garden than non-garden owners in public green spaces, lower scores for neuroticism. The vast majority of participants associated positive meanings (e.g., joy) and family time with private gardens and public green spaces during the pandemic.
Lenaerts et al. (2021), Belgium	Adolescents, adults, and older adults (11352)	Investigate factors that influence nature visits during COVID-19	Nature	Mental health Well-being	Mentally healthy people were more likely to frequent nature than mentally unhealthy people. More than half of the respondents reported feeling more positive after the nature visit during COVID-19.
Lenzi et al. (2021), Basque Country	Audio-recordings in Getxo evaluated by experts (14)	Investigate feelings about natural soundscapes	Nature sounds	Feelings about the soundscape rated by experts	Pleasantness was correlated with perceived natural sounds.
Lesser and Nienhuis (2020), Canada	Adults and older adults (1098)	Investigate changes in COVID-19 related physical activity	Nature	Physical activity	There were no differences between the proportion of active and inactive participants conducting physical activity in natural environments.
Löhmus et al. (2021), Sweden	Adults and older adults (2060)	Investigate if people's mental health and well-being differed depending on greenness exposure during COVID-19	Greenness Nature	Alcohol consumption Sitting score Mental health Vitality Anxiety Depression Perceived stress Cognitive stress	Respondents with lower greenness were more likely to have problematic alcohol consumption and high sitting scores. Greenness was largely unrelated to all other outcomes. Reasons for nature visits changed for frequent nature visitors from pre- to during COVID-19: Stress recovery and relaxation reasons became less important, while health reasons and physical activity became more important.

Luo et al. (2021), China	Urban adult and older adult residents (47)	Investigate motives of urban residents to visit green space during COVID-19	Urban green space	Reasons for visiting green space	Urban green space served as therapeutical place during COVID-19 via providing relaxation, a place to escape from pandemic-related stressors and a break from negative emotions, and mental health promotion via engagement in outdoor activities and physical exercise. Also, urban green space served as meeting place through simple social interactions, hence providing social support.
McCormack et al. (2020), Canada	Children and adolescents (328)	Examine associations between parent's COVID-19 anxiety and physical activity and sedentary behaviors among school-aged children	Park	Child play	Over the majority of respondents reported decreases in play behavior in the park.
Millán-Jiménez et al. (2021), Spain	Undergraduate students (188)	Investigate associations between home characteristics and health during COVID-19	Park/garden and river/sea	Feelings when looking through the window	Feelings of peace were related to park/garden and river/sea window view, which was not experienced when having a building window view. Imprisonment feelings that were linked to window views of other buildings were not present for park/garden or river/sea window view.
Mitra et al. (2020), Canada	Children and adolescents (1472)	Investigates associations between changes in patterns of physical activity, sedentary and sleep behavior patterns and the built environment during COVID-19	Parks	Movement behavior clusters	Park access was related to odds of increased outdoor activities cluster membership for adolescents living in high-density neighborhoods., but not for children.
Mullins et al. (2021), Canada	Adults and older adults (1023)	Investigates associations between home food gardening and attitudes, beliefs and motivations during COVID-19	Garden	Well-being related attitudes, beliefs and motivations concerning home food production	All home food gardeners agreed that gardening is important for mental and physical well-being, including relaxation and physical exercise.
Niles et al. (2021), USA	Adults and older adults (600)	Investigate the association between home food procurement activity and dietary quality during COVID-19	Home food procurement activities	Dietary quality	Gardening was related to increased fruit and vegetable intake for food secure, but not food insecure households. Livestock was related to increased red meat intake. Fishing, foraging, and hunting were unrelated to dietary intake.
Olszewska-Guizzo, Fogel, et al. (2021), Singapore	Adults and older adults (25)	Investigate whether contact with nature and perception of natural environments during home confinement can mitigate the impact of the stay-at-home order on mental health and well-being.	Digital nature Nature areas	Frontal alpha symmetry (FAA) Depressive symptoms Valence Energetic arousal Mood disturbances	After the COVID-19 lockdown, brain activity and responsiveness to landscapes changed, with a general reduction in positive emotions and increased depressive symptoms. Higher nature exposure during the lockdown did not help mitigate depressive symptoms.
Olszewska-Guizzo, Mukoyama, et al. (2021), Singapore	Adults and older adults (12)	Investigate changes in hemodynamic activation patterns of the prefrontal and occipital cortices from pre- to during COVID-19	Digital nature	Cortical hemodynamic brain activation	There was a decrease in average oxyhemoglobin over time for each of the visual conditions. For both green spaces (Urban Park and Neighborhood Landscape), the decrease was in the visual cortex, while for the City Center with no green elements, the marginal decrease was observed in the visual cortex and the frontal eye fields, indicating that City Center scenes induced a hemodynamic pattern associated with stress

					and anxiety, while urban green spaces did not cause such an effect.
Oswald et al. (2021), Australia	Young adults in metropolitan areas (1004)	Investigate associations between potential risk and protective factors and mental illness and well-being during COVID-19	Nature	Complete mental health state	Both incidental and purposive contact with nature were associated with flourishing, while a lack of nature within walking distance was associated with languishing, and lower neighborhood greenness was associated with all three suboptimal mental health states.
Perez-Urrestarazu et al. (2021), mostly Brazil, Greece, Spain, Italy	Adults and older adults (4205)	Investigate the impact of indoor and outdoor vegetation on emotional well-being during COVID-19.	Indoor and outdoor vegetation Green space	Emotional well-being	The large majority indicated that green space was necessary and indoor vegetation were beneficial for their psychological well-being. People who visited green space more frequently and who had a higher number of indoor plants reported better emotional well-being, while this was not observed for outdoor plants. The associations varied by country.
Poortinga et al. (2021), UK	Adults and older adults (5566)	Explore potential benefits of public and private green space during and after the first peak in COVID-19 infections.	Public green space Private green space	Subjective wellbeing Self-rated health	Both during and post-lockdown, longer walking distance was associated with lower subjective well-being and self-rated health. Garden access compensated for longer walking distance during the lockdown for subjective well-being and self-rated health, but not post-lockdown. Associations were largely observed independent of socio-demographic characteristics.
Pouso et al. (2021), Spain, UK, Germany, France, United States, Portugal, Italy, New Zealand, Mexico	Adults and older adults (5218)	Investigate whether maintained contact with outdoor nature spaces was associated with better mental health and mood during lockdown restrictions	Direct and indirect outdoor nature	Mental health Mood	Both general and individual nature accessibility were associated with less anxiety and less depressive symptoms. For people in the strictest lockdown situation in Spain, poor mental health prevalence was lower for people with views of natural area elements while positive emotions were mentioned more often compared to limited or urban views.
Qiu et al. (2021), Australia	National forest park visitors (897)	Investigate the perceived restorative characteristics of natural soundscapes before and after COVID-19 outbreak	Natural soundscapes	Perceived restorativeness	Perceived restorative characteristics of natural soundscapes were mostly higher for the during-pandemic group compared to the pre-pandemic group.
Rhodes et al. (2020), Canada	Adults and older adults (1055)	Investigate socio-ecological correlates of current moderate to vigorous physical activity and COVID-19 related moderate-to-vigorous physical activity shifts	Nature Parks and trails	Moderate to vigorous physical activity COVID-19 related transitions in meeting the physical activity guidelines	Proximity to parks and trails and nature aesthetics were unrelated to moderate-to-vigorous physical activity during the lockdown, changes in moderate-to-vigorous physical activity, and physical activity transition.
Ribeiro et al. (2021), Portugal and Spain	Adults (3157)	Investigate associations between changes in nature contact and mental health during COVID-19	Private and public greenery	Psychological distress Somatization Perceived stress	Maintaining or increasing exposure to private green space and greenery, to public natural spaces and views of nature was associated with less psychological distress and perceived stress as well as somatization. Association between types of natural environments and mental health outcomes differed between Portugal and Spain.

Robinson, Brindley, et al. (2021), mostly UK	Adults and older adults (1184)	Investigate nature's potential health and well-being benefits during COVID-19	Green space	Mental well-being Perceived Stress	The most popular reasons for visiting nature were exercise, stress and anxiety reduction, and relaxation. About half of the respondents agreed that spending time in nature helped them to cope with COVID-19, with some variation across gender and employment status. None of the objective green space assessments was associated with mental well-being or perceived stress.
Rogers et al. (2020), UK	COVID-19 risk group adults and older adults (9190)	Investigate the impact of the COVID-19 lockdown on physical activity	Garden	Physical activity intensity	Respondents without garden access were more likely to start doing less intense physical activity during the lockdown, while having garden access was unrelated to starting more intense physical activity.
Schweizer et al. (2021b), 2021	Strava segments	Investigate cycling behavior in urban and rural public green spaces during COVID-19	Nature parks and urban green space	Cycling	During the lockdown was a significant increase in cycling activity in urban green space, but not in nature parks, which was not maintained post-lockdown.
Soga et al. (2021), Japan	Adults and older adults (3000)	Investigate nature's role in mitigating adverse mental health outcomes due to the pandemic.	Green space Neighborhood greenness	Self-esteem Life satisfaction Subjective happiness Loneliness Depression & anxiety	Green window view and green space use frequency were related to higher self-esteem, life satisfaction, and happiness, and decreased depression and anxiety. Objectively assessed neighborhood greenness was unrelated to all health outcomes.
Spano et al. (2021), Italy	Adolescents, adults, and older adults (3886)	Investigate associations between home greenness and psychological health during lockdown	Greenery at home	Psychological state	All indoor and outdoor green features were related to less negative changes in psychological states, with some variation in relationships between green space type and specific psychological states.
Tarsitano et al. (2021), Italy	Children, adolescents, adults, and older adults participating in guided tours at an urban park (401)	Investigate the social and sensorial-perceptive impact of the guided tour experience on social relationships and well-being after the COVID-19 lockdown	Urban park, dinosaur museum, nature-based laboratory activities	Social relationships Well-being	87% rated the workshop experience as good or excellent regarding the encouragement of friendships or other social relationships. In addition, 95% rated the workshop experience as good or excellent regarding the influence on overall well-being after the pandemic restrictions.
Theodorou et al. (2021), Italy	Adults and older adults (303)	Investigates the relation between gardening and psychopathological distress during the lockdown of the first wave of COVID-19	Garden	COVID-19 related distress Psycho-pathological distress	Gardening was related to lower psychopathological distress and COVID-19 related distress, with the latter one mediating the relationship between gardening and psychopathological distress.
Tomasso et al. (2021), USA	Adults and older adults (529)	Investigates how nature exposure and perceived nature deprivation relate to well-being during COVID-19	Nature	Flourishing	Strong agreement with nature deprivation was associated with a flourishing decline, however, this was only observed for Caucasians.
Tomikawa et al. (2021), Japan	Parents of primary school children (310)	Investigate associations between current life satisfaction and spatial characteristics during COVID-19	Parks	Life satisfaction	Based on text mining analysis, for people living in the Western area, satisfaction with the circumstances surroundings parks was observed, however, for the Eastern

					and Central City area, there was a weak or no relationship observed.
Ugolini et al. (2020), Spain, Croatia, Italy, Lithuania, Slovenia, Israel	Adults (2540)	Investigate human behaviors, perceptions, and attitudes towards urban green space in relation to COVID-19 related restrictions	Urban green space	Motives related to visiting urban green space use Nature deprivation	Motives to visit urban green space were related to enhanced well-being, relaxation, and exercise, with large variations across countries. Feelings of nature deprivation concerned exercising outdoors and meeting others. Agreement for feelings of nature deprivations were dependent on frequency of visiting urban green space during COVID-19 and window views of natural elements.
Ugolini et al. (2021), Italy	Adults and older adults (2081)	Investigate perceptions and behavioral patterns related to urban green space	Urban green space	Motivation to visit green space Feelings of deprivation	Pre-pandemic urban green space visit frequency was positively associated with physical exercise during the pandemic. Motivation to visit urban green space were physical exercise in areas less severely affected by COVID-19 and relaxation in areas severely affected by COVID-19. People not being able to physically visit urban green space reported feelings of deprivation, which was exacerbated if people had no green window view.
van Houwelingen-Snippe et al. (2020b), Northern Europe and North America	Adults and older adults (1203)	Investigate the influence of digital nature on social and mental well-being, and the association between real nature access and loneliness	Digital nature Nature	Connectedness to community Loneliness	Watching nature landscape videos increased feelings of being included in the community. Longer walking time to nature was associated with higher loneliness score, whereas number of nature interactions and garden access were not.
Venter et al. (2021), Norway	Strava data in Oslo	Investigate the longevity of increases in recreational urban green space use during the lockdown	Green and blue space	Walking and cycling	During the lockdown, the strongest increases in walking and cycling were observed in forest and protected areas. The increase was especially strong for adolescents, while a drop was observed for people between 35-64 years.
Vogel et al. (2021), USA	Adults and older adults (990)	Investigate associations between physical activity, stress, and coping strategies in the during early and mid-COVID-19 lockdown	Gardens	Physical activity	During mid-COVID-19 lockdown, participants meeting the physical activity guidelines were more likely to report gardening as a coping strategy.
Weinbrenner et al. (2021), Germany	Urban forest visitors (732)	Investigate the relevance of forests for city residents during the COVID-19 pandemic.	Forests around a German city	Coping and social contacts	A majority if the respondents agreed to visit forest to stay healthy and do sports, reduce psychological stress, and keep in touch with friends and family. Forests became multi-purpose places that allowed to escape from and cope with the pandemic life, and fulfill social and physical activity needs.
Wendtlandt and Wicker (2021), Germany	Adults and older adults (412)	Investigate the effects of nature-based, natural resource-using, and nature-neutral sport activities before and during the COVID-19 lockdown on subjective well-being	Nature-based physical activity	Subjective well-being	Nature-based activities were related to individual's well-being both pre- and during the COVID-19 lockdown, with the relationship being stronger during the lockdown.

Whitehead and Torossian (2021), USA	Older adults (825)	Investigate the impact of COVID-19 on psychological well-being assessed through stressor and coping mechanisms	General nature	Perceived stress Negative affect Positive affect	Some participants mentioned nature as a source of joy during the pandemic. Those who mentioned nature as a source of joy demonstrated enhanced positive affect compared to those who did not mention it, but no differences regarding perceived stress and negative affect were observed.
Xie et al. (2020), China	Adults and older adults (386)	Investigates the role of urban parks during the pandemic period for perceived health and social interaction needs	Urban parks	Mental health Social interactions Perceived health benefits of park visit	Park visit duration was positively related to improved mental health and fulfilling social interactions needs. Especially people with low social interactions levels benefitted from the park use. The number one reason for visiting urban parks was walking.
Yang et al. (2021), China	Children, adolescents, and adults in Hong Kong (661)	Investigates if urban greenery mitigates COVID-19 related decreases in leisure-time physical activity	Urban greenery	Physical activity	People living in greener neighborhoods remained stable in total leisure time physical activity, whereas people living in less green neighborhoods experienced a decline. Additionally, people who lived in greener neighborhoods experienced increased levels of physical activity related to visits to country parks.
Zabini et al. (2020), Italy	Adults and older adults (75)	Investigates the restorative effects of forest vs. urban videos during COVID-19	Digital nature	Anxiety	Participants watching the forest-based audio video displayed lower anxiety scores after watching the video, whereas participants watching the urban-based audio video maintained or increased anxiety, indicating acute effects. No one-week pre-post differences were observed for either condition.
Zagalaz-Sánchez et al. (2021), Spain	Children (837)	Investigate whether children's living conditions during the COVID-19 related confinement period influenced their daily activities	Garden	Screen time Physical activity Free play Psychosocial aspects	Children with a garden had the lowest television time and the highest physical activity and free play levels. Parents of children with a garden perceived them happier and less tired compared to parents of children without a garden. No other differences were observed.
Zhuo and Zacharias (2020), China	Young adults (284)	Investigates associations between leisure types and living environments with subjective well-being during COVID-19.	City greenness	Overall well-being Mental well-being Function well-being Social well-being	View from home on city greenery was unrelated to all types of well-being.

Discussion

This article presents the findings of a scoping review conducted to examine the current research on the relationship between natural environments, psychosocial health, and health-related behaviors in the COVID-19 pandemic. The overall trend of the literature included in our scoping review suggests that nature holds the potential to mitigate the negative effect of COVID-19 on psychological health and physical activity during the COVID-19 pandemic. However, this relationship is complex and varies regarding specific population characteristics, nature type, and geographical location.

After extracting some descriptive characteristics of the included studies, we applied a thematic analysis approach following the guidelines of Braun and Clarke (2006) to identify and categorize the articles in the pre-determined categories nature, representing the types of nature investigated during the COVID-19 pandemic and health and health-related behaviors, representing health outcomes and behaviors investigated regarding nature during COVID-19. During our analyses, a third primary category was developed concerning heterogeneity and variability regarding the association between nature and health.

The descriptive characteristics revealed that most studies applied a cross-sectional study design, which is consistent with studies that have been conducted prior to COVID-19 (Collins et al., 2020; Zhang et al., 2021). Most studies were conducted in Western countries, and the ethnic background of the participants was rarely considered or even reported. Research in non-Western countries was rare. The most common samples comprised the general population, typically adults, while vulnerable populations were less commonly included in the sampling. This highlights a gap in the research as the mental and social health consequences of this pandemic are expected to be the strongest and long-lasting among vulnerable populations (Kola et al., 2021). This highlights a gap in the literature when considering previous research, which supports that people who are psychologically vulnerable benefit from green space (Tost et al., 2019), and that the COVID-19 pandemic and related restrictions had the most severe impact on people that were already struggling with mental health challenges (O'Connor et al., 2021; Quittkat et al., 2020; Ting et al., 2021). Furthermore, people with vulnerability risk specific to the COVID-19 pandemic should be considered. For example, the imposed restrictions are expected to have exacerbated the “modern epidemic” (Jeste et al., 2020) of loneliness (Hwang et al., 2020), while

a study conducted prior to COVID-19 showed that green space could decrease the risk for loneliness (Astell-Burt et al., 2021). Hence, more research among vulnerable groups regarding the relationship between nature and psychosocial health and health behaviors in the COVID-19 context is warranted.

Regarding the first primary theme of our review, the type of nature investigated, we found that gardening was the most commonly nature-based activity that was investigated. Other frequently studied contexts were more general investigations into green space and vegetation cover. The thematic focus on general green space and vegetation cover is consistent with previous reviews (Frumkin et al., 2017; Hartig et al., 2014). Other types of nature, including blue space, such as rivers or lakes (Britton et al., 2020), or the network of natural areas within a certain area that are specifically planned for ecosystem services, called green infrastructure (Nieuwenhuijsen, 2021), have been neglected. The focus of researchers on investigating private gardens, including gardening activity, seems to be specific to the pandemic context. These settings facilitated contact with nature while adhering to stay-at-home orders (e.g., lockdowns). For example, a recent study in Brazil showed that having a home garden was the most important predictor of mental health, while visiting urban parks was deemed less relevant (Marques et al., 2021). Thus, especially during pandemic times, researchers should be concerned with the types of nature exposure and access to nature at home. An additional gap in the literature emerges regarding research in digital and virtual nature experiences. The research interest around digital nature and health-related benefits has generated some interest in pre-COVID-19 times, suggesting that virtual nature experiences supplement real-life nature experiences and can promote human-nature interactions and connections (Litleskare et al., 2020). Indeed, a previous study showed that digital nature exposure, including high definition TV, 360° video, and virtual reality digital nature enhances mood and reduces boredom (Yeo et al., 2020). Especially during COVID-19 times, the benefits of digital nature experiences became obvious, specifically for places where leaving the house for recreational purposes was prohibited. Beyond this pandemic, research on digital and virtual nature experiences should be expanded to facilitating people's contact with nature that may not have the opportunity to visit nature in real-life. For example, a recent study reported that nature videos and nature sounds decreased stress levels assessed via cortisol and galvanic skin response in incarcerated adult males (Nadkarni et al., 2021). This shows the positive potential of digital nature experiences for people with limited nature

access to nature. Hence, potential benefits of digital nature contact should also be investigated in other settings that may only have limited nature access opportunities, such as elderly care homes, clinical care settings, or areas of urban degradation. Digital nature also allows investigators to evaluate the role of different nature types, which may illuminate our understanding regarding which natural features provide the strongest psychosocial health benefits (Bratman et al., 2019).

Regarding the operationalization and measurement of nature, studies reported a limited assessment of the characteristics of nature exposure. In self-reported measures, for example, participants were mostly asked about the frequency and duration of their nature visits, without further specification of the nature type or a clear definition of nature. Regarding device-based quantitative assessment, the most common approach was the Normalized Difference Vegetation Index (NDVI), consistent with previous findings (Ekkel & De Vries, 2017), which assesses the degree of vegetation and distance to the nearest natural areas, calculated across different buffer distances. However, none of those measures enables firm conclusions about the quality of the nature area or the green space to be elucidated. This is a major gap in the research, considering that previous studies proposed the use of quality indicators in explaining health outcomes and behaviors, including quality indicators such as shelter, safety, amenities and absence of litter in the natural area (Knobel et al., 2021; Van Dillen et al., 2012), as well as nature characteristics, such as biodiversity (Knobel et al., 2021; Marselle et al., 2021; Sandifer et al., 2015). Beyond nature quality, the nature experience itself should be more considered, for example, individual preferences, the level of human-nature interaction (e.g. viewing a lake vs. swimming in a lake), or other contextual factors such as the season (Bratman et al., 2019; Masterton et al., 2020).

Regarding the second primary theme, health and health behaviors, psychological health received the most interest regarding nature during COVID-19. This seems plausible as the COVID-19-related restrictions had a strong impact on mental health within different populations across the globe (Bu, Mak, et al., 2021; Kola et al., 2021; O'Connor et al., 2021; Xiong et al., 2020). More specifically, our analysis showed that the topics of most interest among researchers included well-being and general mental health, stress, mood and emotions, as well as depression and anxiety. In that sense, nature is considered a resource to prevent mental illness and disease, with the large majority of studies supporting the role of nature in mitigating COVID-19's impact on mental health. However, what has been less examined

regarding nature were psychological constructs that empower people to protect and promote their own health, reflected through few codes regarding coping and recovery and few investigations regarding associations between nature and social health in the COVID-19 pandemic context. Following a salutogenic approach (Antonovsky, 1987), health promotion aims to provide resources that empower people to promote and protect their own health through, amongst others, creating supportive environments and promote personal development and skills (WHO, 1986). Moreover, in the context of mental health and COVID-19, researchers advocate that it is crucial to identify, understand, and optimize social resources, coping, and resilience, especially for vulnerable groups (Holmes et al., 2020). For example, Bu, Mak, et al. (2021) demonstrated that talking to friends and family member as well as self-care activities were most frequently used for mental health support during COVID-19, especially by people with pre-existing mental health conditions. Considering that nature exposure has been shown to have similar effects on well-being than social interactions (Killingsworth & Gilbert, 2010; Tost et al., 2019), future research about human-nature interactions should explore nature, not simply as a preventative factor but additionally as a resource that promotes positive psychological health (e.g., resilience, social support, and personal growth). Again, digital and virtual nature interventions could be a valuable resource for mental health promotion, especially when integrated into e- and mHealth interventions (Naslund et al., 2015). However, although a recent meta-review found good support for digital (non-nature) interventions regarding mental health in terms of usability, safety, acceptance, and satisfaction, most of the interventions were concerned with the treatment and prevention of mental disorders rather than mental health promotion (Rauschenberg et al., 2021). We suggest that future research should go beyond a deficit-based approach and should focus instead on nature as a resource for mental health promotion both through real-life and digital nature experiences, termed a strength-based approach.

Regarding health behaviors, the role of nature regarding physical activity received the most interest from researchers in the field. This is not surprising, given the numerous health benefits of physical activity across different populations (Bull et al., 2020; Chaput et al., 2020). Furthermore, research findings support the contention that overall physical activity decreased during COVID-19 (Paterson et al., 2021; Stockwell et al., 2021). However, about half of the studies investigating physical

activity asked participants to give reasons for visiting nature, with physical activity being one of them, or asked them to rate the importance of nature for physical activity during COVID-19. Other physical activity assessments were performed via self-report inventories, while only one study used device-based assessment via a step-counter (Hino & Asami, 2021b). Two other studies used Strava to assess walking and cycling (Schweizer et al., 2021a; van Houwelingen-Snippe et al., 2020a). However, these studies do not report whether specific features of the natural environment were relevant to the motivation of people to go there for physical activity, nor did these studies provide information on whether physical activity in natural environments displaced other types of physical activity that were currently not possible due to the COVID-19 restrictions (e.g., organized sport). Both in the context of COVID-19 and beyond, it may be worthwhile to examine which features of the natural environment provide affordances for physical activity, given that nature-based physical activity may be a resource that promotes mental health to a greater extent than physical activity in other non-natural settings (Lahart et al., 2019; Mnich et al., 2019). Device-based assessment of physical activity combined with geolocation tracking technology could be valuable to obtain detailed insights on physical activity in natural environment contexts (Jankowska et al., 2015). Unfortunately, other health behaviors (e.g., sleep) were rarely investigated. However, from a conceptual point of view, investigations between specific types of nature or nature-based activity and health behaviors could be valuable in the context of COVID-19. For example, in two studies, most participants reported negatively changing their eating behaviors during the COVID-19 lockdown (Deschasaux-Tanguy et al., 2021; Robinson, Boyland, et al., 2021). In contrast, gardening activity was related to improved dietary intake (Beavers et al., 2020; Davis et al., 2011). Hence, as home gardening received increased interest during COVID-19 in some areas (Giraud et al., 2021), there may be sustained effects on health eating behaviors, which warrants further study.

Regarding the third primary theme of our review, heterogeneity in the nature-health (behavior) relationship, it appears that the associations vary based on different features. Most common were investigations based on gender and age differences, with no clear direction. For example, while one study reported that feelings of solace and respite and feelings of reconnection were more likely to be reported by males (Astell-Burt & Feng, 2021a), another study reported that shorter distance to the nearest parks mitigated a step decline in older women, but not older males (Hino & Asami, 2021b). The

underlying mechanisms for these differences remain to be investigated and are essential for the planning of nature-based solutions and interventions when aiming to contribute to the sustainable development goals (Faivre et al., 2017; Maes & Jacobs, 2017; UN, 2015). For instance, in a qualitative study, women indicated that fear of violence hinders positive well-being experiences when visiting an urban park in Mexico during COVID-19 (Huerta & Cafagna, 2021). The issue of different mechanisms for different populations in the nature-health relationship has been summarized in a review by Masterton et al. (2020). They synthesized the evidence regarding mechanisms of green space interventions for mental health and investigated which mechanisms work for whom, distinguishing between clinical and non-clinical populations. For example, they found that green space improves mental health via the mechanism “escape/getting away”, which works particularly well for people with an existing mental health diagnosis, while the mechanism “shared experiences” was highlighted in nearly all studies they had included (Masterton et al., 2020). Hence, to create effective nature-based solutions and interventions, different mechanisms for different populations should be further investigated and considered.

Furthermore, heterogeneity has not only been investigated regarding population characteristics, but also with regards to nature characteristics, e.g., between different park types (Cheng et al., 2021; Lee et al., 2021), as well as nature quality, in the studies of this review operationalized as higher greenness and vegetation (Cheng et al., 2021; Huerta & Cafagna, 2021). The few studies investigating heterogeneity and disparities regarding nature types in relation to mental health mirror a research gap that researchers has been identified prior to COVID-19 (Bratman et al., 2019). Hence, future endeavors should focus on identifying the underlying reasons for disparities in the nature-health association and provide interventions that facilitate an inclusive approach to ensure that all citizens can have a safe and positive nature experience. Finally, heterogeneity was investigated regarding geographic regions, with most attention being paid to variability in the nature-health relationship between different countries, which may result from the diverse COVID19 restrictions implemented in different locations. We recommend that future reviews would apply a comparison of WEIRD (Western, Educated, Industrialised, Rich, and Democratic) vs. non-WEIRD countries to explore the bias in sampling, favoring the former (Henrich et al., 2010).

To the best of our knowledge, this is the first scoping review summarizing the available research regarding the relationship between nature and psychosocial health or health behaviors. However, there are some limitations that should be considered. In the first step, the study screening process was conducted based on title, followed by the screening based on abstract before full texts were obtained. Thus, it cannot be ruled out that some eligible studies were overlooked in this process. We only included articles published in German, English, or Scandinavian language, thus, studies published in other languages were not included. Furthermore, we focused on psychosocial health and health behaviors based on the emerging literature that consistently demonstrated that psychosocial health and health behaviors deteriorated during COVID-19. We also focused on the benefits that humans gain from the natural environment but did not consider the impact of humans on the natural environment based on a planetary health understanding (Whitmee et al., 2015). Additionally, given the nature of a scoping review, we did not assess study quality in the 82 articles that were included. Hence, for future reviews investigating associations between nature and health or health behaviors, it would be useful to also investigate associations between nature and physiological health and to assess the quality of the included articles. In addition, a comprehensive review that also considers the positive and negative impact of human-nature interactions on the natural environment, such as wildlife rebounding and increases in illegal nature activities such as hunting (Bates et al., 2021), as well as potential co-benefits (Inauen et al., 2021), would be valuable to obtain a holistic planetary health understanding (Whitmee et al., 2015).

Conclusion

The COVID-19 outbreak had a significant impact on people's psychosocial health and health behaviors. This study synthesized available evidence regarding the relationship of nature with psychosocial health and health behaviors during COVID-19. In sum, the available research suggests that nature mitigates the negative impact of COVID-19 on well-being and mental health and nature's importance for physical activity during the pandemic. In addition, research gaps in the COVID-19 context were identified regarding I) nature characteristics that promote psychosocial health and health behavior, II) the impact of digital and virtual nature, III) psychological constructs relating to mental health promotion, such as resilience, IV) health behaviors other than physical activity, V) underlying mechanisms regarding

heterogeneity in the nature-health relationship based on the study population, type of nature, and geographic characteristics, and VI) research focusing on vulnerable groups. Beyond the identified research gaps, future studies should ideally apply longitudinal designs and follow-up on participants to investigate possible long-term associations between nature's impact on health and health-behavior outcomes during COVID-19.

Although the COVID-19 pandemic will likely be over or at least mitigated by increased vaccination against the virus, the COVID-19 pandemic serves as an example of a stressful event on the societal level. Stressful events on the societal level have occurred in the past, such as the global financial crisis 2008-2009, and have a high potential to occur again in the future, for example, other zoonotic diseases (Quammen, 2012; Walsh et al., 2020) or extreme events such as heatwaves as a consequence of climate change (Thiery et al., 2021). Therefore, natural environments may be a valuable resource to build resilience before, mitigate the negative impact during, and allow individuals to promote their health during the stressful event.

Declarations of interest

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