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A systematic review

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Effectiveness of nature-based walking interventions in improving mental health in adults: a systematic review

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Abstract

Nature-based walking interventions represent a low-cost, eco-friendly activity, designed to assist people in maintaining physical well-being and improving their mental-health status. This systematic review aims to evaluate the evidence regarding the effectiveness of nature-based walking interventions in the improvement of mental health outcomes in adults. This paper draws upon Applied Social Sciences Index & Abstracts (ASSIA), PsycINFO, MEDLINE, EMBASE, the Web of Science Core Collection, Doctoral thesis databases (ProQuest), and manual searches. Due to the heterogeneity of the eligible studies, a narrative synthesis was employed. The present review includes 1,209 adult participants, of whom 336 were female; it also involves 17 discrete studies. The evidence from this systematic review suggests that nature-based walking interventions can indeed improve adults' moods, sense of optimism, mental well-being, and nature connectedness. They simultaneously mitigate stress, anxiety, and negative rumination. In addition, compared with *urban* walking, nature-based walking interventions may bring greater benefits *vis-à-vis* anxiety and rumination. This review contributes to the synthesis of evidence for nature-based walking interventions, and identifies several research gaps around the topic. In clinical practice, nature-based interventions may be used to relieve one's negative mood, stress, and anxiety. To enhance treatment efficacy, however, they should be combined with formal modes of psychotherapy.

Keywords Mental health · Nature-based interventions · Green walking · Review

Introduction

Background

A variety of risk factors in relation to urbanisation and urban lifestyles (such as overcrowding, physical inactivity, and a lack of nature connection) have led to negative health outcomes, including the increasing prevalence of mental health disorders (Ventriglio et al., 2021; World Health Organization, 2022). Unhealthy lifestyles have been shown to lead

to a variety of psychological and physical health problems. For example, the association of physical inactivity and sedentary lifestyles with obesity is well established (Martínez-González et al., 1999), but the same factors also drive type-2 diabetes, cardiovascular problems, hypertension, heart disease, dementia, and chronic pain (Knight, 2012; Lavie et al., 2019). They are, furthermore, linked to anxiety and depression (Moselhy et al., 2012). Prevention and amelioration of these serious health issues are necessary in order to reduce health-care demands and treatment costs (Health, 2020).

Physical exercise, such as walking in natural settings, has been proposed as a novel and desirable approach to mental-illness prevention and health promotion (Bird, 2007; Frumkin et al., 2017). There is substantial evidence, on the one hand, that cognitive function and mood may be elevated by physical exercise (Kelly et al., 2018a), while the latter may also mitigate depression and anxiety (Carter et al., 2021; Gaia et al., 2021; Kanning & Schlicht, 2010; Lam & Riba, 2016; Xiang et al., 2020). Walking is more accessible and convenient than other forms of physical activity. Easily incorporated into everyday life (Marselle et al., 2014),

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it confers benefits regarding cardiovascular fitness, physical resilience, psychological-stress reduction, and positive mood (Kelly et al., 2018b; Sianoja et al., 2018; Song et al., 2015; Sturm et al., 2012). On the other hand, the use of outdoor spaces, including natural settings, has been recognised as a determinant of public health (Department of Health, 2014).

The positive influence of “nature contact” on well-being and mental health is supported by a growing evidential corpus, which several reviews have addressed (e.g., Bowler et al., 2010; Capaldi et al., 2015; Gascon et al., 2015; Hartig et al., 2014; Health Council Netherlands, 2004; Ohly et al., 2016; Pritchard et al., 2020; Richardson et al., 2017; van den Berg et al., 2015; World Health Organization, 2016). Indeed, there is substantial evidence for the direct beneficial effects of nature contact on mental health, such as: (1) restorative benefits, including reduction of psychological stress, depression and anxiety, and attention restoration (also reduction in mental fatigue and improvement in cognitive function); and (2) mental well-being improvement (Lovell et al., 2018). The advantages of different forms of nature exposure for psychological welfare are also increasingly confirmed (Beute et al., 2020; Sandifer et al., 2015; Townsend et al., 2018). Moreover, there is evidence (despite mixed outcomes) that physical activities, encouraged by natural settings, play a mediatory role between nature and mental health (Hartig et al., 2014).

It is suggested that there is a synergistic relationship between the benefits of physical exercise and the benefits of nature connection (Shanahan et al., 2016). Evidential quality and research design may vary, but, as noted by Hartig (2014) and numerous others (Bowler et al., 2010; Dzhambov et al., 2019), the mental-welfare advantages associated with nature contact are diverse, and they exploit several pathways. This remains true, although types, frequency, duration and intensity vary.

A range of theories have been proposed to explain why walking in nature might have a positive effect on well-being. Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989) proposes that connections with nature engage people in “effortless” attention towards their environments. “Effortless attention” is also associated with “involuntary attention”, i.e., attention that inherently captures stimuli. This contrasts with “direct” or “voluntary” attention, which is controlled, and which requires greater consumption of mental energy (Berman et al., 2012). Excessive direct attention may lead to mental fatigue and stress (Hartig et al., 1991). Nature walking, conversely, provides respite from voluntary attention, which (subliminally or passively) is replaced by the involuntary form.

Other theories regarding the mental-health benefits of nature connection are the Biophilia Hypothesis (Kellert &

Wilson, 1993) and the Stress Reduction Theory (Ulrich et al., 1991). These propose that, since humans have evolved in a natural habitat, their love of nature is innate and instinctive. Furthermore, Stress Reduction Theory originated from an empirical study, which demonstrated that looking at scenery with natural features, such as vegetation or water, generates pleasant emotions, as well as sentiments such as curiosity, enjoyment, and tranquillity. These are restorative, and they promote alertness after stress (Ulrich, 1984).

In addition to these theories, research on place attachment and its relationship with mental health (see, e.g., Ramkissoon et al., 2013; Townsend et al., 2018) has provided valuable insights into how the environment, including natural spaces, can shape individuals’ perceptions and experiences, ultimately impacting their well-being.

In the context of extant theory and the possible psychological advantages of nature exposure, it is clear that walking in *natural* environments, as opposed to artificial ones, may confer particular benefits. There are, in fact, a growing number of studies to confirm this hypothesis. According to a systematic review of 23 published studies (Thompson, Coon et al., 2011), promising effects for self-reported mental well-being after exercise in nature were *not*, by contrast, found after the same exercise indoors. Affectively and cognitively, a 50-minute walk in a natural setting may confer superior benefits to a similar walk in a non-natural environment, according to one experimental study (Bratman, Daily et al., 2015). Another experimental study found that group walks in nature may be associated with a variety of mental health benefits, such as lower depression and enhanced mental well-being (Marselle et al., 2014). Similarly, Roe and Aspinall (2011) found restorative benefits in rural walking but not in town-based walking. Still, because of dubious methodological quality, heterogeneous measures of outcome and the sheer variety of settings examined, these findings cannot be seen as conclusive (Barton et al., 2009; Thompson Coon et al., 2011). For instance, a recent systematic review found that nature walks were useful for state anxiety but not for *generalised* anxiety, and the effects on depression were mixed (Kotera et al., 2021). The same review, however, failed to examine other mental-health outcomes potentially associated with nature walks.

For a better understanding of the extra benefits conferred by nature-based walking, this paper aims systematically to review and evaluate the evidence for the efficacy of green space-based walking interventions on adult mental health. To control features of the natural environment, the study will specifically address green space, while other spaces, such as “blue-space”, may require additional investigation. For the sake of convenience, non-green space and urban space are treated as synonymous within this review.

Review questions

The aim of this systematic review is to evaluate the effectiveness of nature-based walking interventions in improving mental health outcomes amongst adults. The review questions are as follow:

- a. Do adults’ mental-health outcomes improve after nature-based walking interventions, compared to the period before the intervention?
- b. Is there a greater improvement in people’s mental health following nature-based walking interventions, compared with walks in non-green spaces?

Methods and materials

This systematic review has been registered in the PROSPERO systematic review database (ID: CRD42018091431). The first search for the present review occurred in August 2018. The latest update took place in January 2023. The Cochrane database was screened to ensure there were no similar reviews in this field.

Inclusion and exclusion criteria

In line with the PICOS guidance, which was developed from the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2019), and the PRISMA statement (Liberati et al., 2009), studies were included if they were based on randomised controlled trials, between-subject experimental or quasi-experimental designs, or within-subject designs with control groups/conditions that compared the effects of nature-based walking interventions on mental health, on the one hand, with those of a suitable control.

Table 1 Eligibility criteria

Item	Criteria
Population (P)	Adults (aged 18 and above).
Intervention (I)	Nature-based walking intervention, walking in green spaces, such as urban parks, farmland, forests, national parks, hills, landscape fields (including places such as golf courses).
Comparators (C)	Non-green outdoor spaces, such as urban area without significant greenery
Outcomes (O)	Mental health was defined broadly to include measures such as: mood, mindfulness, anxiety, depression, subjective well-being, quality of life.
Methods and design	Quantitative research using randomised and non-randomised controlled designs (i.e. Quasi-experimental design), within-subjects and between subjects with pre-post-tests.
Language	Written in English.
Types of publication	Peer-reviewed publications, grey literature (e.g. dissertation, PhD thesis).

To be eligible, studies were obliged to contain group comparisons for well-being-related outcomes, and/or pre-post discrepancies. The studies were analysed to identify within-subject and between-subject designs.

The participants included in the studies had to be adults, but there was no restriction on their mental health condition. In other words, they may or may not have presented with active mental illness. Studies comprising participants with a diagnosable physical-health condition were excluded from this review, because the latter mainly focuses on changes for *mental* health-related outcomes, rather than those of physical ability. Any interventions involving indoor walking and/or virtual experimental settings, with pictures or videos of natural green environments, were excluded. The eligible studies might thus be concerned with a) mental-health improvements in the nature-based walking intervention, and/or b), whether well-being improvements in the nature-based walking intervention are greater than those in the control group. Table 1, below, provides a summary of the criteria for inclusion and exclusion.

Search strategy and selection process

The formal search involved use of a range of bibliographic databases, as follows: Applied Social Sciences Index & Abstracts (ASSIA), PsycINFO, MEDLINE, EMBASE, the Web of Science Core Collection, and Doctoral thesis databases (ProQuest).

The following keywords were used with commands “AND” and “OR”: “natural green space*” OR “green*” OR “natural green area*” OR “natural surrounding*” OR leafy OR grassy OR verdant OR “natural environment*” OR outdoor* OR outside OR country* OR rural OR nature * OR walk* OR ramble* OR stroll* AND “well-being” OR wellbeing OR “well being” OR mental health* OR “sleep quality” OR mindfulness OR anxi* OR depress* OR distress* OR stress* AND “adult” NOT “qualitative” NOT “cross-sectional” NOT “review”. Manual searches were also applied to the reference lists for the screened studies, in order to mitigate possible impediments deriving from selection bias. No additional, qualifying studies were found through manual searches, although one relevant unpublished dissertation was identified (Goulding et al., 2018).

Rayyan was used to manage references. Citations retrieved were downloaded, and duplicates were removed. Independent eligibility screening was applied to abstracts and titles. A second reviewer (Peilin Lin) then independently assessed the articles for eligibility.

Data extraction

The data extraction was independently completed by the author and the second reviewer. In order to support reliability and consistency, a discussion was held before the final version was agreed upon. The following items are pertinent to the review question: study design, participants' characteristics, the nature of intervention and the control, the number of walking sessions, measurements, pre-post effect size, main findings, and key limitations.

Quality assessment

The Revised Cochrane Risk of Bias Tools for Randomised Trials (ROB-2) were deployed to assess RCT bias risk. This generated categories of high bias risk, "some concerns", and low risk (Sterne et al., 2019). For the non-randomised studies, observational studies, existing criteria and guidelines were adapted from the SIGN 50 Checklist (Scottish Intercollegiate Guidelines Network, 2019). The applicability of this tool was discussed with co-authors, to ensure the suitability of using it in the present review.

The rating of each quality criterion was classified as follows: well-covered (3 points); adequately addressed (2 points); poorly addressed (1 point); and not addressed (0 points). The rating "well-covered" was assigned when the evaluation categories were clearly reported and could be identified by the reviewers. When detailed descriptions were absent, but the article provided sufficient information for identification, this was deemed "adequately addressed". "poorly addressed" was assigned when there was no relevant, or only limited, information provided in the article. For the sake of accuracy, nonetheless, the numerical ratings were not deemed final, because the criteria were not of genuinely equal importance. The ratings were finally stated as "++", "+", or "-", in order to represent high quality (overall rating ranging from 18 to 24), medium quality (overall rating ranging from 12 to 17), and relative low quality (overall rating ranging from 0 to 11), respectively. Each of the included studies was assessed independently by the second reviewer and the author. The agreement of quality ratings between these two appraisers reached 75%, and final ratings were decided after discussions.

Results

Included studies

There were 5,710 studies identified during the initial search phase, and one dissertation was requested for inclusion by the authors. Studies were excluded during the initial title

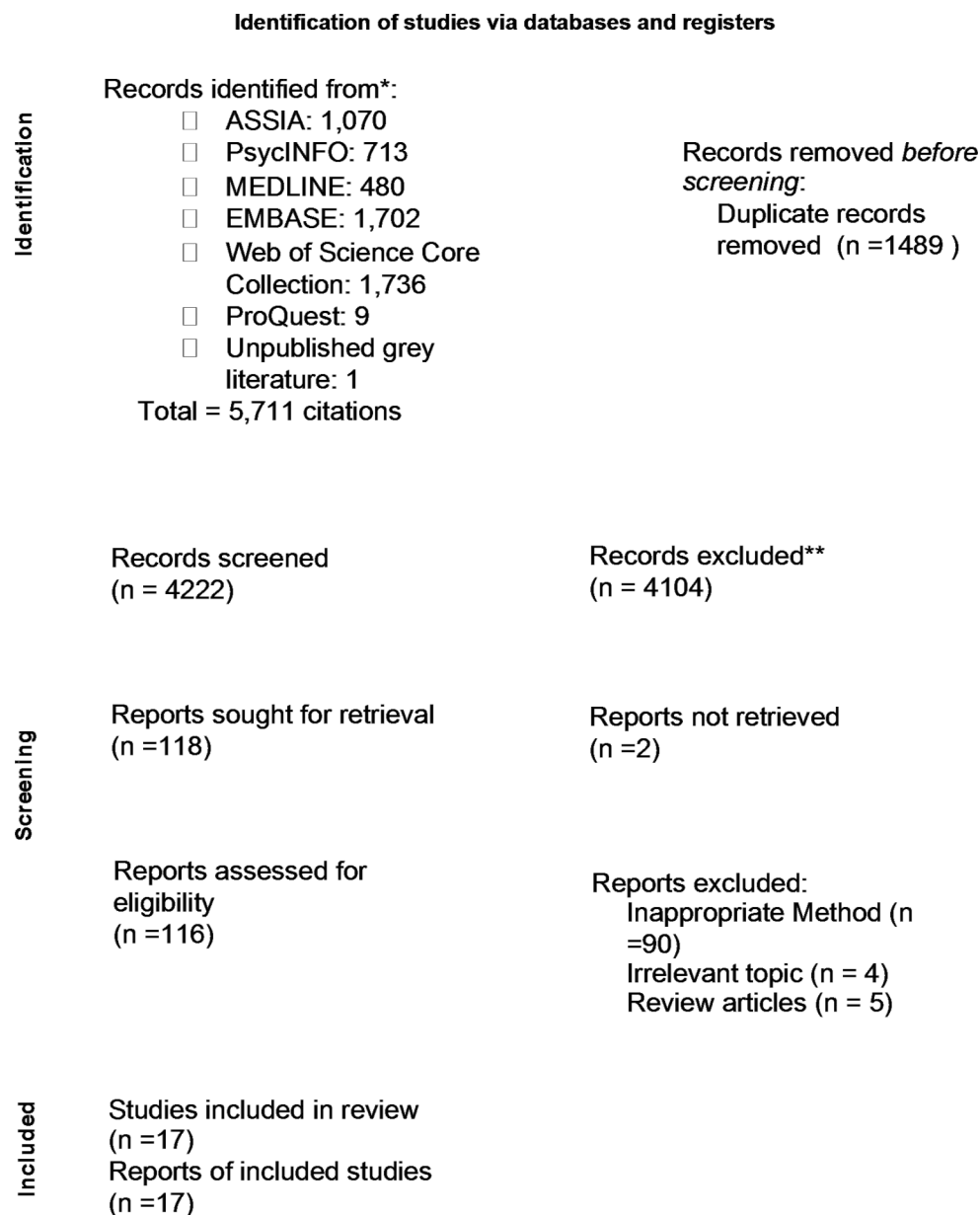
and abstract screening. After duplication, 4,222 studies were found, and of these, 118 studies with full texts were screened for further eligibility. Finally, and overall, 17 studies were deemed suitable for inclusion in this systematic review. The selection process for the included studies is shown in a PRISMA flow chart (see Fig. 1). Additional information on exclusions can be found in Appendix A.

Study characteristics

Key characteristics of the included studies are outlined in Table 2, below. The included studies ($n=17$) contained 1,209 participants, among whom 336 participants were female. Most of the studies included the general population, without diagnosed mental illness ($n=15$). Only two studies included participants with a major depressive disorder (MDD) (Berman et al., 2012) or those who experienced depression or anxiety (Keenan et al., 2021). The participants ranged in mean age from 19.6 to 40.34 years, and the overall number of male participants in the included studies exceeded that of females. The included studies were mostly conducted in the USA ($n=6$), Japan ($n=4$), and the U.K ($n=3$). More details can be found in Fig. 2.

Intervention characteristics varied among the studies in multiple aspects. Variations occurred, for example, in frequency and duration of walking, and location. The nature-based walking interventions took place in forests (Hassan et al., 2018; Keenan et al., 2021; Koselka et al., 2019; Shin et al., 2011; Song et al., 2018, 2019), urban parks (Aspinall et al., 2015; Berman et al., 2012; Bratman et al., 2015a; Goulding et al., 2018; Johansson et al., 2011; Song et al., 2014, 2015), landfill (Geniole et al., 2016), and other natural landscapes with grassland (Bratman, Daily et al., 2015; de Brito et al., 2019; Mayer et al., 2009b). Conversely, the comparator walking took place downtown (Berman et al., 2012; Johansson et al., 2011; Shin et al., 2011; Song et al., 2019), in urban areas (Bratman, Daily et al., 2015; Bratman, Hamilton, Bratman et al., 2015a, b; Geniole et al., 2016; Hassan et al., 2018; Song et al., 2014, 2015, 2018), in busy shopping streets (Aspinall et al., 2015; Goulding et al., 2018; Koselka et al., 2019), in residential areas with traffic roads (Koselka et al., 2019), and in concrete areas with buildings (Keenan et al., 2021; Mayer et al., 2009a). In terms of length, the walking sessions varied between 90 min and 15 min. Two studies employed multiple walking sessions, namely, 30-minutes sessions for five consecutive days (Keenan et al., 2021), and once-weekly sessions for three weeks (de Brito et al., 2019). All the other studies included here, however, deployed single walking sessions only.

For the measured mental-health outcomes, mood was the most frequently measured outcome. This was generally

Fig. 1 Flow chart of study selection

evaluated either via the Positive Affect and Negative Affect Schedule (PANAS) (Berman et al., 2012; Bratman et al., 2015a; de Brito et al., 2019; Goulding et al., 2018; Keenan et al., 2021; Koselka et al., 2019; Mayer et al., 2009a) and/or the Profile of Mood State (POMS) (Shin et al., 2011; Song et al., 2014, 2015, 2018, 2019). The State-Trait Anxiety Inventory (STAI) was also used to assess anxiety (Bratman, Daily et al., 2015; de Brito et al., 2019; Hassan et al., 2018; Koselka et al., 2019; Song et al., 2014, 2015, 2018, 2019). Rumination and mindfulness levels were measured, respectively, by the Reflection Rumination Questionnaire (RRQ) (Bratman, Daily et al., 2015; Bratman, Hamilton, Bratman et al., 2015a, b; Goulding et al., 2018), and the State Mindfulness Scale (SMS) (Goulding et al., 2018). To measure distress and stress levels, the Bodily Distress Syndrome

(BDS) (de Brito et al., 2019; Koselka et al., 2019) checklist and the Perceived Stress Scale (PSS-10) (Koselka et al., 2019) were used.

To evaluate overall mental health and positive emotions, respectively, some authors deployed the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) (Goulding et al., 2018; Keenan et al., 2021) and the Eight-item Flourishing Scale (EFI) (Johansson et al., 2011). Only one included study measured the degree of nature connection via the Connectedness to Nature Scale (CNS) (Keenan et al., 2021). Other measurements included EEG (Aspinall et al., 2015; Hassan et al., 2018), and arterial spin labelling (ASL, a neuroimaging method to record brain activity in prefrontal cortex) (Bratman, Hamilton et al., 2015). This

Table 2 Key characteristics of the included studies

Author Year Country	Sample Characteristics	N/Age	Design	Treatment / Control Inter- ventions (or conditions)	No. of Session(s) / Walking duration	Outcome Measurements	Pre-Post Effect Size of Green Walking	Group*Time effect size of Green Walking	Main Findings	Key Limitations
Aspinall et al., 2015, UK	General	N=12 (female=4). Mean Age=30.08	Time-series with pre-post-test.	Walking in urban park / Walking in urban shop- ping street.	Single ses- sion. / 25 min for both routes.	Mobile EEG to record excite- ment frustration, arousal, and meditation.	$R^2=0.06$ (medium effect size)	[N.A.] Walking	Walking from urban to green spaces reduced participants' arousal, frustration, and engagement, increased mediation.	The EEG recorder was occasionally not streaming data. No Follow-up tests.
Berman et al., 2012, USA	Major Depres- sive Disorder (MDD)	N=19 (female=12) Mean age=26	Counter-balanced within-subject design.	Walking in a park with tree line / Walking in downtown.	Single session. / 50–55 min for both groups.	PANAS	Positive affect: $d=0.23$ (small effect size). Negative affect: $d=-0.58$ (medium effect size)	[N.A.]	Mood improved after walk- ing for both groups of par- ticipants. Nature-based green walking brought additional positive affect than urban walking.	Small sample size. Difficult to moti- vate participants to take nature walks. No follow-up tests.
Bratman et al., 2015a, b (a). USA	General	N=60 (female=33). Mean age=22.9.	RCT with pre-and-posttest.	Walking in a park with paved path through grass- land, scattered shrubs, and oak trees. / Walking in a busy street.	Single ses- sion. /	STAI; RRQ; PANAS.	STAI: $d=0.46$ (small effect size). RRQ: $d=0.29$ (small effect size). Positive affect: $d=0.61$ (medium effect size). Negative affect: $d=0.68$ (large effect size).	[N.A.]	Compared to walking in urban, the nature-based green walking decreased greater levels of anxiety, rumination, and negative affect, as well as maintained the more positive affect.	Participants' char- acteristics have not been considered as a co-variable. No follow-up tests.
Bratman et al., 2015a, b (b). USA	General	N=38 (female=18) Mean age=26.6.	RCT with pre-and-posttest.	Walking in grassland with scattered oak trees and shrubs. / Walk- ing in an urban area.	Single ses- sion. /	RRQ; ASL (mea- suring sgPFC).	RRQ: $d=0.34$ (small effect size). sgPFC: 1.01	[N.A.]	Nature experience reduced rumination and sgPFC activation. Nature-based green walking has shown more effective on reducing rumination compared with the urban walking.	Did not reveal the mechanism of how nature experience reduced negative repercussions in urban life. No follow-up tests.

Table 2 (continued)

Author Year Country	Sample Characteristics	N/Age	Design	Treatment / Control Inter- ventions (or conditions)	No. of Session(s) / Walking duration	Outcome Measurements	Pre-Post Effect Size of Green Walking	Group*Time effect size of Green Walking	Main Findings	Key Limitations
Brito et al., 2019. USA	General.	N=23 (female = 19). Mean age = 49.3.	Non-RCT cross- over design	Walking in the Minnesota Landscape Arboretum. / Walking in paved side- walks adjacent to medium traffic roads in a medium-den- sity residential development area	3-weeks once- weekly sessions. / Both routes took 50 min.	STAI; PANAS; BDS task.	[N.A.]	[N.A.]	Green walking reduced state anxiety and improved posi- tive affect better than sub- urban walking, with green walking eliciting somewhat greater but not significant reductions in negative affect versus suburban walking. Directed attention did not seem to benefit from either green walking or suburban walking in this sample.	No simultaneous random assign- ment to treat- ment sequence. Outcomes were all measured using self-reported questionnaires. Mistaken wording in scales that could impact the results. Limited sample generalizability (majority being high-educated women of middle- to high-income from a single geographic area).
Gould- ing et al., 2018. UK.	General.	N=37 (female = 24). Mean age = 24.67.	RCT with pre- and-posttests, and follow-up test after two weeks.	Walking in a large park con- taining hills. / Walking in a busy shopping street.	Single ses- sion. / Both routes were 2 miles long and took around 45 min.	WEMWBS; RRQ; SMS; PANAS.	Positive affect: d = 0.66 (medium effect size) Rumina- tion: d = 0.71 (medium effect size) Mindful- ness: d = 1.18 (large effect size) Mental well- being: Not reported	Positive affect: $\eta^2 = 0.046$ (small effect size). Rumination: $\eta^2 = 0.001$ (small effect size). Mindfulness: $\eta^2 < 0.001$ (small effect size). Mental well- being: Not reported	Both walking groups showed significant improvement on positive affect, mindfulness, and on reduction of rumina- tion. Increased mindfulness was only associated with decreased rumination. There was no significant effect of mental well-being on time, but significant interaction effect of time and group was found, indicating that walking in greenspaces contributed to greater levels of well-being than urban group.	RRQ was designed as a trait mindful- ness measure- ment, it may not identify short-term changes. Sample bias.

Table 2 (continued)

Author Year Country	Sample Characteristics	N/Age	Design	Treatment / Control Inter- ventions (or conditions)	No. of Session(s) / Walking duration	Outcome Measurements	Pre-Post Effect Size of Green Walking	Group*Time effect size of Green Walking	Main Findings	Key Limitations
Geniole et al., 2016. Canada.	General	N=31 (no female). Mean age=24.61.	Within-subject design with pre- and posttests.	Walking in naturalized landfill with green spaces. / Walking in an urban area.	Single ses- sion. / Both routes took 25 min.	The Affect Grid (measure mood and arousal).	Mood: $d=0.59$ (medium effect size). Arousal: N. A.	[N.A.]	Participants' positive mood increased after walking in greenspaces and decreased after walking in urban.	Urban area used in the study was not 'urban' enough. Sample bias (only included males). Un-standardized measurements. Limited sample representative- ness – only young females and males were recruited. Only single nature condition introduced.
Hassan et al., 2018. China.	General	N=60 (female = 30). Mean age = 19.6.	Crossover study design with pre- and post-tests.	Walking in a bamboo forest. / Walking in an urbanized area.	Single ses- sion. / Both routes took 15 min.	EEG; STAI.	$d=0.32$ (within- subject); Beta wave: $d=0.42$ (within- subject); $d=0.72$	[N.A.]	Mean meditation and atten- tion scores were significantly increased after walking in a bamboo forest. Walking in the bamboo forest improves mood and significantly reduces anxiety.	Single group. Small sample size. Lack of valid measurements. No follow-up.
Johans- son et al., 2011. Sweden.	General.	N=20 (female = 10). Mean age = 24.2.	Time series within-subject design.	Walking in a park with hardwood trees and grassland. / Walking in street with moderate traffic.	Singe session. / 40 min for both routes.	EFL.	Revital- ization: $\eta^2=0.084$. Positive engage- ment: $\eta^2=0.015$. Anxiety/ Depres- sion: $\eta^2=0.067$. Anger: $\eta^2=0.415$	[N.A.]	The intervention increased positive affect and reduced negative affect. Nature- based green walking was more effective on increasing revitalization compared with urban walking.	Single group. Small sample size. Lack of valid measurements. No follow-up.
Koselka et al., 2019. USA.	General	N=38 (female = 20). Mean age = 22.9.	Between-subject design with pre- and- posttests.	Walking on a forest path. / Walking along a busy road. / A period of activities of daily living.	Single ses- sion. / Both routes take 50 min.	PANAS; STAI; PSS-10; BDS;	PA: $d=0.51$. NA: $d=0.61$. Anxiety: $d=0.57$. Stress: $d=0.55$.	[N.A.]	Walking in forest path group experienced significantly increase in participants' positive affect, significantly reduce in negative affect, anxiety, and perceived stress. Walking along a city roadside either provided less improvements (negative affect) or declined par- ticipants wellbeing (positive affect, perceived stress).	Small sample size and short duration due to the restric- tion of a pilot study. Potential influence from an unintentional wording mistake in the STAI scale used.

Table 2 (continued)

Author Year Country	Sample Characteristics	N/Age	Design	Treatment / Control Inter- ventions (or conditions)	No. of Session(s) / Walking duration	Outcome Measurements	Pre-Post Effect Size of Green Walking	Group*Time effect size of Green Walking	Main Findings	Key Limitations
Keenan et al., 2021. UK.	Individuals with experiences of depression and/ or anxiety	N= 50 (female = 30). Mean age = 40.34.	Between-subject design with pre- and- posttests.	Walking in a forest park in lakeside, beach, moun- tain, forest, and bog areas. / Walking in urban areas through hous- ing estates, town centers, a town park and main roads	30-minutes sessions for five consecu- tive days.	WEMWBS; PANAS; CNS;	Nature connec- tion: $\eta^2 =$ 0.34. Positive affect: η^2 = 0.42. Negative affect: η^2 = 0.66. Wellbeing = $\eta^2 =$ 0.29 (large effect size for all above variables)	[N.A.]	Significant effect of time by condition on all Variables. Post-hoc tests indicated a significant increase in nature connected- ness and positive affect in the nature versus an urban walk at post and follow-up. Negative affect decreased in nature walk at post intervention, while well-being was signifi- cantly greater in the nature walk at follow-up.	Small sample size of included clinical patients. Poten- tial bias due to lack of pre-made walking lead- ing instructions. Limited investiga- tion in influence of the severity of depression and/or anxiety.
Mayer et al., 2009. USA.	General	N= 76 (female = 51). Mean age not reported.	Between-subject design with pre- and-posttests.	Walking in an open land with wood and grass. / Walk- ing in a con- crete area near a building with an adjacent parking lot.	Single session. / Not reported.	PANAS	Not specified.	[N.A.]	Participants in green space walking group reported significantly greater positive emotions than urban walk- ing. Both groups reported almost equal levels of nega- tive emotions.	Lack of statistics that has been reported. No follow-up.

Table 2 (continued)

Author Year Country	Sample Characteristics	N/Age	Design	Treatment / Control Interventions (or conditions)	No. of Session(s) / Walking duration	Outcome Measurements	Pre-Post Effect Size of Green Walking	Group*Time effect size of Green Walking	Main Findings	Key Limitations
Shin et al., 2011. South Korea.	General	N=60 (female = 25). Mean age = 23.27.	Counter balanced RCT	Walking in an urban forest park with pine trees. / Walking in downtown.	Single session. / Both groups walked 50–55 min.	POMS	Tension-Anxiety: $d = -0.99$. Depression: Dejection: $d = 0.90$. Anger-Hostility: $d = 0.57$. Vigor-Activity: $d = 1.19$. Fatigue-Inertia: $d = -1.05$. Confusion: $d = -1.53$.	[N.A.]	Participants' mood significantly improved after walking in forest. Significant within-subject differences were found for the urban walking across all sub-scales excluding Depression-Dejection and Confusion.	Pre-environmental behaviours have not been investigated. No follow-up.
Song et al., 2014. Japan.	General	N=17 (no female). Mean age = 21.2.	Within-subject design with pre-and-posttests.	Walking in an urban park with significant greenery. / Walking in an urban area.	Single session. / 15 min walking for each route.	POMS; STAI.	Not specified.	[N.A.]	Walking in both routes can decrease anxiety but walking in greenspace improved greater levels of mood state and decreased anxiety than walking in urban.	Small sample size. Sample biased (only included male). Short walking duration.
Song et al., 2015. Japan.	General	N=23 (no female). Mean age = 22.3.	Within-subject design with pre-and-posttests.	Walking in an urban park with hardwood trees. / Walking in an urban area.	Single session. / 15 min walking for each route.	POMS; STAI.	Not specified.	[N.A.]	Walking in both routes can decrease anxiety but walking in greenspace improved greater levels of mood state and decreased anxiety than walking in urban.	Small sample size. Sample biased (only included male). Short walking duration.

Table 2 (continued)

Author Year Country	Sample Characteristics	N/Age	Design	Treatment / Control Inter- ventions (or conditions)	No. of Session(s) / Walking duration	Outcome Measurements	Pre-Post Effect Size of Green Walking	Group*Time effect size of Green Walking	Main Findings	Key Limitations
Song et al., 2018. Japan.	General	N= 585 (no female). Mean age= 21.7.	Crossover study design with pre- and post-tests.	Walking in forest. / Walk- ing in a city area.	Single session. / 15 min for both routes.	POMS; STAI.	Not specified.	[N.A.]	Walking through forest areas decreased the negative moods of “depression-dejec- tion”, “tension-anxiety”, “anger-hostility”, “fatigue”, and “confusion” and improved the participants’ positive mood of “vigor” compared with walking through city areas. Further- more, a significant correla- tion was found between participants’ trait anxiety levels and their changes in the subscale of “depression- dejection” of POMS after walking through forest areas.	Differences in sites according to region might intro- duce confounding factors. Restricted generalizability due to limited sample representa- tiveness. Lack of measuring on other relevant wellbe- ing outcomes. Limited control on participants’ prior expectations and experience with forests.
Song et al., 2019. Japan.	General	N= 60 (female = 60); Mean age= 21.0.	Crossover study design with pre- and post-tests.	Walking in well-main- tained forest areas. / Walk- ing in city areas located either down- town or near a Japan Railway station.	Single session. / 15 min for both routes.	POMS; STAI.	Not specified.	[N.A.]	Scores for the comfortable, relaxed, and natural param- eters and vigour subscale of POMS were significantly higher, whereas scores for negative feelings, such as tension-anxiety, depression- dejection, anger-hostility, fatigue, and confusion, were significantly lower, as were the total mood disturbance of POMS and the anxiety dimension of the STAI.	Limited sample representative- ness – only healthy female university students in their 20s were recruited. The only physi- ological indices used were for autonomic nervous activity.

Table 3 Quality assessment for non-randomised observational studies

	Study	Study design	Recruitment and Inclusion Criteria	Allocation Process	Groups similar at baseline	Addressing missing data	Valid and reliable measurement	Follow-up measure	Appropriate analysis	Total score	Overall rating
1	Aspinall et al., 2015	2	1	0	0	0	3	0	2	8	-
2	Berman et al., 2012	2	3	2	2	3	3	0	2	17	+
3	Brito et al., 2019	3	3	1	3	3	3	0	3	19	++
4	Geniole et al., 2016	3	2	0	2	3	3	0	3	16	+
5	Hassan et al., 2018	3	2	0	0	0	3	0	3	11	-
6	Johansson et al., 2011	3	2	0	2	0	3	0	2	12	+
7	Koselka et al., 2019	3	3	1	3	1	3	0	3	17	+
8	Keenan et al., 2021	3	3	1	3	0	3	2	3	18	++
9	Mayer et al., 2009	3	1	2	1	0	3	0	2	12	+
10	Song et al., 2014	2	1	0	1	0	2	0	1	7	-
11	Song et al., 2015	2	1	0	1	0	1	0	1	6	-
12	Song et al., 2018	2	1	0	0	0	3	0	3	9	-
13	Song et al., 2019	1	1	1	2	0	3	0	3	11	-

Notes. Well-covered = 3, Adequately addressed = 2, Poorly addressed = 1, Not addressed = 0

reported that nature-based walking interventions can significantly improve positive, and decrease negative mood, with medium (Koselka et al., 2019) and large effect sizes (Keenan et al., 2021), respectively.

Moreover, a further study that evaluated mood via the Affect Grid (Geniole et al., 2016) detected an increase in participants' positive mood after green space walking, with medium effect sizes. Nevertheless, the psychometric properties of the Affect Grid have not been clearly reported (Russell et al., 1989), and this reduces the reliability of its results. One study reported significantly different emotional change from two walking locations, having measured emotion via EEG (Aspinall et al., 2015). This study may have yielded relatively invalid results, however, because it only used mobile EEG instruments to measure emotion. The sample size ($n=12$) was also particularly small. Johansson and his colleagues (Johansson et al., 2011) used the Eight-item Flourishing Scale (EFI) to measure emotion, and significant changes were found after the nature-based walking intervention. This included decreased negative emotion and increased positive emotion, with medium effect sizes.

Additionally, of three RCT studies that measured mood, two indicated that positive mood improved, and negative mood reduced, after nature-based walking, with small to medium effect sizes (Bratman, Daily et al., 2015; Goulding et al., 2018). One RCT study, conversely, found a large effect size of changes in negative mood decrease and positive mood improvement (in vigorous activity) (Shin et al., 2011).

Amongst those studies, participants in two experienced depression and anxiety, alongside both negative and positive mood changes after nature-based walking. The effect sizes in this case ranged from small to large (Berman et

al., 2012; Keenan et al., 2021). Overall, taking the results of quality assessment and participants' characteristics into account, the included studies show that changes of positive and negative mood after nature-based walking can be effectively detected.

Anxiety Of the included studies, eight examined participants' levels of anxiety via STAI. Seven of these were non-randomised observational studies, but only one was an RCT study, and this detected lower levels of anxiety (with medium effect size) after greenspace walking. Nevertheless, only *one* of the included observational studies reported effect size (Koselka et al., 2019). The remainder did not report effect sizes in anxiety variation, or at least, they failed to do so appropriately. For the RCT study (Bratman, Daily et al., 2015), a significant effect of time was found, with small effect size, indicating that participants' anxiety level decreased after nature-based green-walking interventions.

Rumination and Mindfulness Amongst the included studies, three evaluated rumination using the Rumination and Reflection Questionnaire (RRQ), and all of these employed the RCT experimental design. These studies showed lower rumination after nature-based green walking than before, with small (Bratman, Daily et al., 2015; Bratman, Hamilton, Bratman et al., 2015a, b) to medium effect sizes (Goulding et al., 2018). Mindfulness was also measured by the State Mindfulness Scale (SMS). This evinced a large effect of time, suggesting an improvement in state mindfulness following green space walking (Goulding et al., 2018).

Other mental-health outcomes First, mental well-being was measured in two studies via WEMWBS. One study failed to detect a significant effect of time (Goulding et al., 2018), although the other, in terms of mental

well-being change, indicated large effect of time (Keenan et al., 2021). The latter also involved more subjects ($n=60$) than the Goulding study ($n=36$). Nevertheless, Goulding's study employed RCT, and only single walking sessions were delivered, with green walking taking place in an urban park. Keenan's study deployed a non-RCT between-group study, and the authors ran a consecutive five-day walking intervention in a forest park. As both studies were rated as either "low risk" or "high quality", it is very likely that nature-based green walking could improve one's mental well-being.

Second, two observational studies addressed the issue of stress levels. Changes in both perceived stress and body stress of the participants were found, with medium effect size (Koselka et al., 2019). One study, however, failed to report effect size (de Brito et al., 2019).

Third, the degree of nature connection was measured by only one non-RCT between-group designed study, and here, a large effect of time was found (Keenan et al., 2021). This implies an affective improvement following nature-based walking interventions.

Lastly, three of the included studies used either EEG or a brain-imaging tool (ASL) to measure changes of rumination, emotion, and meditation (Aspinall et al., 2015; Bratman et al., 2015b; Hassan et al., 2018). These studies reported medium to large effect size of changes, in the reduction of rumination and increased meditation and optimistic emotion.

The synthesised findings, in summary, indicate that optimistic emotion, mental well-being, positive mood and nature connectedness effectively improved after nature-based green walking. Meanwhile, levels of rumination, anxiety and stress were effectively reduced.

Review question two: the effectiveness of nature-based walking interventions on mental health outcomes

Only four RCT studies were included in the present systematic review, which measured participants' mood, anxiety, rumination, mindfulness, and mental well-being. First, two studies measured mood using PANAS and POMS; these reported an interaction effect in time*group. The same two studies comprised only a single session of walking, while one indicated a statistically significant positive-affect improvement in *both* walking groups, and no group difference was detected (Goulding et al., 2018). Another RCT study found a significant interaction effect in time*group on mood, indicating that nature-based green walking generated greater levels of positive mood and reduced negative mood, as compared with urban walking (Bratman, Daily et al., 2015). These two studies were rated as "low risk" for bias, and the characteristics of the participants were similar.

While the participants in Bratman's study (Bratman, Hamilton, Bratman et al., 2015a, b) were more numerous ($n=60$) than those of Goulding (Goulding et al., 2018; $n=37$), these particular findings may have been influenced by discrepancies in sample size and characteristics.

Secondly, only one included RCT study compared differences of anxiety reduction between green and urban walking groups (Bratman, Daily et al., 2015). This study detected a significant interaction effect in time*group in anxiety, indicating that walking in green spaces reduced anxiety compared with walking in urban settings. Effect size, however, was not reported.

Thirdly, three included RCTs compared differences of rumination changes between two walking groups. Of these, two indicated a greater reduction in rumination from green space walking rather than urban walking, since they evinced a significant interaction effect for time*group (Bratman, Daily et al., 2015; Bratman, Hamilton, Bratman et al., 2015a, b). Nonetheless, one RCT study did not find significant group differences in changes in rumination or state mindfulness level between the two walking groups (nature versus urban) (Goulding et al., 2018). As Bratman's (Bratman, Hamilton, Bratman et al., 2015a, b) study and Goulding's (Goulding et al., 2018) study employed the same instrument to measure rumination, and their walking settings were similar, the differences in their findings may be a result of sample size and other undetected variables. The study of Goulding et al. (2018) was the only one to conduct a follow-up test for all variables. Nonetheless, no between-group differences were identified for mental well-being, mood, or rumination.

The non-RCT studies reviewed ($n=13$) provided consistent evidence that walking in green spaces, such as nature-based environments or forest areas, tends to have a greater positive impact on people's mental health compared to walking in non-green spaces, such as urban areas or city streets. Following walking in such green environments, reduced negative affect, and improvements in positive affect and mood, were registered by several studies. For instance, Koselka et al. (2019) reported that walking in a forest-path group led to increased positive affect and reduced negative affect, anxiety, and perceived stress. Conversely, fewer positive effects, or even detrimental ones, were generated by walking along an urban roadside. Furthermore, Johansson et al. (2011); Mayer et al. (2009b) noted that nature-based green walking resulted in greater improvements in positive affect and revitalisation, compared to urban walking. Aspinall et al. (2015) found that walking from urban to green spaces reduced arousal, frustration, and engagement, while increasing meditation. Song et al. (2014, 2015, 2018, 2019), meanwhile, conducted multiple studies and consistently found that walking in green spaces not only reduced

anxiety, but also improved mood state and decreased negative feelings, as compared to walking in urban areas. After forest-based walking, the same authors noted correlations between variations in particular mood scales (e.g., depression-dejection) and levels of trait-anxiety.

Notwithstanding the heterogeneity of natural settings and research design in the studies, the presence of natural elements and the peaceful environment in greenspaces do seem to contribute to various mental health benefits. Overall, the non-RCT studies under review suggest that a greenspace-based walking intervention is more beneficial for mental health than walking in non-green spaces.

Generally, the evidence suggests that nature-based walking interventions may effectively reduce participants' anxiety, negative affect, perceived stress, and rumination. They may also enhance meditation and increase positive affect. A significant group difference in the measurement of mental well-being was not found. Nonetheless, in comparison with non-nature walking, there are additional overall advantages in health-related outcomes for nature-walking groups / conditions, as opposed to non-natural environments.

Discussion

The present systematic review aims to investigate the effectiveness of nature-based walking interventions on mental health outcomes in adults. The evidence from 17 studies, 16 of them published in academic journals, has been synthesised, and gaps in the research evidence are discussed below.

Regarding the two review questions, this evidence suggests that adult participants' positive mood, optimistic emotion, mental well-being, and nature connection effectively improved following nature-based, green-walking interventions. Moreover, in comparison with urban walking, there was a significant decrease in rumination, anxiety and stress. No significant between-group differences were found in mood and measurements of well-being, in terms of the RCT studies. The non-RCT studies in this review indicated that nature walking provided additional benefits in enhanced positive affect and mindfulness level. Overall, then, and to reiterate, nature-based walking interventions would appear to generate significant dividends in mental health, as compared with non-green environments.

These findings are consistent with a recent systematic review, which indicated that various physical activities in nature (i.e., hiking, jogging, walking, etc.) enabled people to reduce their anxiety and negative affect, while improving positive affect (Wicks et al., 2022). The current systematic review also found effects of green walking on mental

well-being, mindfulness, stress, nature connectedness, and rumination.

The findings of mood enhancement and restorative benefits, such as fatigue reduction after greenspace walking interventions, may support the Attention Restoration Theory (ART), to the effect that the natural environment can restore human attention (from directed attention) and reduce fatigue (Kaplan, 1995). Nonetheless, one study indicated that, from pre-walk to post-walk, there was no improvement in directed attention for either condition (de Brito et al., 2019b). Moreover, another study reported that nature exposure was not associated with improved attentional control (Geniole et al., 2016). Therefore, although there may be some synergistic benefits of walking and nature exposure for mood improvements, the mechanism proposed by ART may need further investigation.

It is, furthermore, possible to situate the findings of the present study in a wider context, notably in terms of mental health improvements in a post-COVID world. For instance, Ramkissoon (2021) proposed a conceptual framework of integrative body-mind interventions for well-being improvement, using the COVID-19 place confinement as the context. In a similar vein, Ramkissoon (2022) developed and proposed “a single integrative model of adaptive social bonding interventions (psycho-social, nature, and digital), wellbeing and quality of life.” This emphasised the role of nature-based therapies as a means of enhancing mental health. The framework and model proposed by Ramkissoon provides valuable perspectives on the multidimensional aspects of well-being, and the potential benefits of interventions that integrate mind-body approaches. This expansion allows us to appreciate how nature-based walking can contribute to various dimensions of well-being *beyond* mental health, such as physical and spiritual well-being.

The present study has reaffirmed the efficacy of nature-located green walking in the context of various mental health outcomes. Nonetheless, there was either a lack of external validity in, or an inconsistency between, the studies included in this review. Although all the deployed measurements related to mental health, the experimental designs that the studies employed were heterogeneous, so that no definite conclusions could be reached. More specifically, the reviewed studies conducted experiments to examine whether green walking brings greater psychological benefits than non-green walking, due to the effects of connectedness with nature. Conversely, the degree of nature connectedness for participants, in the two situations, was only evaluated by one study (Keenan et al., 2021). Therefore, it is not possible to assess the extent to which environmental differences (green versus non-green) contributed to the different psychological outcomes of walking. Further studies are required to explore whether the degree of connectedness with nature predicts

differences in psychological outcomes, *vis-à-vis* walking in nature versus walking in urban environments.

In some of the included studies, sample sizes were extremely small. Four studies mentioned this weakness as a limitation that may lead to inconclusive results. Secondly, in the Song et al. studies (Song et al., 2014, 2015), only male participants were involved, which reduced the sample's representativeness *vis-à-vis* a realistic population (Song et al., 2014, 2015). Third, result validity may be reduced by the assessment techniques deployed by some of the studies. For example, the Aspinall study (Aspinall et al., 2015) used a low-cost headwear EEG recorder that occasionally failed to stream data, causing some data to be missed. It is also possible that this headwear negatively influenced mood while walking. Goulding (Goulding et al., 2018), meanwhile, noted that some vocabulary in PANAS may be outdated, and this may have caused some confusion amongst participants. The Johansson study (Johansson et al., 2011) noted the low internal consistency of certain measurements employed. Lastly, Geniole (Geniole et al., 2016) and Shin (Shin et al., 2011) observed that different types of environment may generate different results, and that we should consider the pro-environmental behaviour of participants before their walking interventions. Improvements in mental well-being, for instance, may be related to previous, environmentally friendly lifestyles.

Each study employed controlled trials to test the differences between walking in greenspaces and non-greenspaces. Nonetheless, synthesis of the results via meta-analysis remains challenging, due to discrepancies in research design (e.g., the review included both between-subject and within-subject studies). The authors decided not to run a meta-analysis to display the overall effect size of green walking amongst adults, for several reasons. First, the two Bratman RCT studies did not provide SD and mean values, which are prerequisites for such an analysis. Second, the included studies used various measurements that could not be combined. Even though the fix-effect model may address some of these issues, there were still a few studies that poorly presented the descriptive data, while evincing some missing values.

Well-being may also be affected by other vectors, such as weather or the duration of walking. The included studies in this review were conducted in very different countries, with distinctive weather patterns and natural features. Accordingly, weather conditions should be considered and controlled as an important variable, in order properly to interpret the results of these studies.

In order to assess the mental-health efficacy of nature-based, green walking more precisely, additional randomised/controlled trials will be needed. These should be done with a randomisation process, pre/post *and* follow-up test, as well

as valid measurements implemented to control for external variables and experimental biases. Most importantly, it is necessary to explore the mediators between green walking and the improvement of mood, and other measures of mental well-being.

RCTs for nature-based walking may reveal what types of green space are most beneficial for mental well-being. The studies included in this review varied in many ways, making the mechanisms through which nature walking influences mood difficult to discern. For most of the included studies, total intervention durations varied, and there were frequent disparities in the type of green space utilised. Although it is believed that natural environments are beneficial, one study argued that natural green spaces are not *always* restorative: densely wooded areas, and the natural environment, may even trigger stress and fear (Gatersleben & Andrews, 2013). In fact, in most of the included studies, there was little discussion of the natural environments in question, and the latter were often poorly described.

While the overall conclusion may align with existing literature in this field, our review specifically focuses on the effects of *nature-based walking on mental health outcomes*, consolidating the evidence from a range of studies. By systematically synthesising the available evidence, we provide a comprehensive overview of the specific mental health benefits associated with this intervention. Meanwhile, the current review acknowledges that our second research question yielded a null result. Null findings, while they present interpretative challenges, can still contribute to the corpus of knowledge by indicating fields where further research is required. By reporting these null results, we aim to encourage future research to explore potential factors that may influence the overall well-being outcomes of nature-based walking.

The contribution of this systematic review extends beyond the immediate findings. The systematic review approach we have employed allows researchers, practitioners and policymakers to access a consolidated and critically appraised body of literature on this topic. This can serve as a valuable resource for evidence-based decision-making, and the development of interventions to promote mental health.

Conclusions

Nature-based walking is an environmentally responsible and relatively inexpensive intervention. This review demonstrates that it helps people maintain and improve their mood and mindfulness, and it also reduces anxiety and rumination. While further research is certainly needed, the present results confirm the desirability of supporting mental health by providing accessible green spaces (e.g., additional urban

parks). Nonetheless, nature-based walking should not only be viewed as an “intervention” in terms of public health. Rather, people in general should be encouraged to incorporate green walking into their normal lifestyles. Meanwhile, there is a need for additional research on the use of nature-based interventions within formal psychotherapies, to enhance creativity and increase therapeutic benefits.

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Data Availability A data-availability statement is not available, as the present study is a systematic review.

Declarations

Conflict of interest There is no conflict of interest to disclose for this manuscript.

Informed consent This manuscript has not involved human participants, so consent forms are inapplicable for this study.

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