Effect of nature prescriptions on cardiometabolic and mental health, and physical activity: a systematic review

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Nature prescriptions are gaining popularity as a form of social prescribing in support of sustainable health care. This systematic review and meta-analysis aims to synthesise evidence on the effectiveness of nature prescriptions and determine the factors important for their success. We searched five databases from inception up to July 25, 2021. Randomised and non-randomised controlled studies featuring a nature prescription (ie, a referral or an organised programme, by a health or social professional, to encourage spending time in nature) were included. Two reviewers independently conducted all steps of study selection; one reviewer collected summary data from published reports and conducted the risk of bias assessment. Random-effect DerSimonian-Laird meta-analyses were conducted for five key outcomes. We identified 92 unique studies (122 reports), of which 28 studies contributed data to meta-analyses. Compared with control conditions, nature prescription programmes resulted in a greater reduction in systolic blood pressure (mean difference –4·82 mm Hg [–8·92 to –0·72]) and diastolic blood pressure (mean difference –3·82 mm Hg [–6·47 to –1·16). Nature prescriptions also had a moderate to large effect on depression scores (post-intervention standardised mean difference –0·50 [–0·84 to –0·16]; change from baseline standardised mean difference –0·42 [–0·82 to –0·03]) and anxiety scores (post-intervention standardised mean difference –0·57 [–1·12 to –0·03]; change from baseline standardised mean difference –1·27 [–2·20 to –0·33]). Nature prescriptions resulted in a greater increase in daily step counts than control conditions (mean difference 900 steps [790 to 1010]) but did not improve weekly time of moderate physical activity (mean difference 25·90 min [–10·26 to 62·06]). A subgroup analysis restricted to studies featuring a referring institution showed stronger effects on depression scores, daily step counts, and weekly time of moderate physical activity than the general analysis. Beneficial effects on anxiety and depression scores were mainly provided by interventions involving social professionals whereas beneficial effects on blood pressures and daily step counts were provided mainly by interventions involving health professionals. Most studies have a moderate to high risk of bias. Nature prescription programmes showed evidence of cardiometabolic and mental health benefits and increases in walking. Effective nature prescription programmes can involve a range of natural settings and activities and can be implemented via social and community channels, in addition to health professionals.

Lancet Planet Health 2023; 7: e313–28

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Introduction

Extensive evidence indicates contact with nature is associated with good social, mental, and physical health.[1–3] These potential benefits include favourable pregnancy outcomes[4] and improved mental health[5–9] to reduced risks of cardiometabolic[10–13] and neurodegenerative diseases[14–19] in older adults. Although addressing the well documented inequities in green space[20] is warranted, improving the provision of green spaces will be insufficient to ensure everyone is able to access and benefit from them.[21]

Nature prescriptions share similarities with social prescribing, a new model of care involving referral to a link worker who designs a community support programme based on what an individual finds intrinsically motivating (eg, music groups, social sports, conservation, volunteering). A nature prescription typically involves a health professional (eg, a general practitioner) or social professional (eg, a counsellor or welfare officer) recommending a patient to spend a fixed amount of time a week in a natural setting, such as a park.[22] Nature prescriptions have emerged as a potential solution to enable and empower people to spend more time in nature when that was not previously the case. Nature prescriptions are an adjunct to conventional health care, such as the educational and pharmaceutical treatment of non-communicable diseases.[23] It is widely considered that the benefits of nature prescribing will reach far beyond clinical outcomes, such as increasing social connectedness[24] and pro-environmental behaviours.[25]

Large nature prescription programmes have been implemented in many countries, such as a nationwide green social prescribing programme in the UK to tackle mental ill health.[26] There is a need for more evidence on this new form of social prescribing. Several reviews have examined the benefits of nature-based therapies;[27–29] however, these reviews were broad and not necessarily specific to nature prescriptions. To our knowledge, two systematic reviews have been conducted on nature prescription to date. A review by Kondo and colleagues[30] searched for nature prescriptions by outpatient physicians and identified 11 studies published by June 2019. Kondo and colleagues concluded that the evidence was too sparse to find patterns in health outcome responses. Another review by Garside and colleagues[31] focused on social prescribing programmes targeting mental health in the UK. The authors identified 36 studies and adopted a realistic approach to examining the programmes' health effects. The substantial increase in interest in and implementation of new nature prescription programmes[32,33] provides an opportunity to investigate the benefits of nature prescriptions (which can include both prescriptions by health professionals and social professionals) with quantitative systematic review methods.

Therefore, this systematic review aims to identify and synthesise evidence for effective nature prescriptions and to determine the factors that are important for their success. We examine whether nature prescriptions improve social, mental, and physical health; the design characteristics of nature prescriptions; and the potential channels to dispense a nature prescription.

Methods

This is a systematic review with a meta-analysis. Reporting of this review was guided by the PRISMA guidelines.[34] This review was not registered a priori.

Search strategy

We searched the following databases for peer-reviewed articles from inception up to July 25, 2021: MEDLINE via Ovid, Embase via Ovid, PsycINFO via Ovid, CINALH via EBSCO, and CENTRAL and Cohcrane Database of Systematic Review via Cochrane Library. Trial registries and grey literature were not searched. The search was supplemented by a manual search of reference lists from systematic reviews of similar nature-based interventions. The search strategy combines terms describing nature prescriptions, nature-based therapies, and interventions aimed at increasing nature exposure (appendix 1 pp 2–8).

See Online for appendix 1

Study selection

Two reviewers (P-YN and HR-A) independently screened all titles and abstracts in duplicate and excluded studies that did not meet the inclusion criteria (table 1). Full texts of selected articles were reviewed by one reviewer (P-YN) and checked by a second reviewer (H-RA). Disagreement was resolved by discussion with senior reviewers (XF and TA-B). All stages of study screening were conducted using Covidence (Veritas Health Innovation, Australia). We excluded interventions with a dietary focus as these have been previously investigated.[35]

For **Covidence** see https://www.covidence.org/

Data collection

One reviewer (P-YN) extracted data with a standardised extraction form. Data extracted included characteristics of studies, participants, interventions, and outcomes. Study characteristics included study design, sample size, and location. Participant characteristics included social background, pre-existing medical conditions, and age groups, as defined in the eligibility criteria. Interventions were characterised on the basis of the nature setting where the intervention took place, types of activities undertaken by participants, whether the nature setting was indoor or outdoor, and the referring institutions. A referring institution is defined as any institution with an established medical or social connection to the patients, who referred the participants to the intervention or organised the intervention for the participants. We recorded no referring institution if the participants were recruited through standard trial recruitment methods, such as mass emails, in-person recruiters, social media, or public bulletins. The referring institution was subsequently classified as health institution if it was part of the health system (outpatient clinics, hospitals, health centres, etc), or as a social institution if it was outside the health system (welfare centres, social service providers, long-term care facilities, universities, etc). We evaluated the design of all interventions to see whether they showed aspects of the Social Cognitive Theory framework for behavioural change. The theory stipulates that learning a new behaviour (in this case, an increased engagement with nature) is facilitated by internal and external social reinforcement. These reinforcements can be summarised in three groups of factors: cognitive factors, environmental factors, and behavioural factors.[36] We categorised the outcomes measured as physical, psychological and cognitive, or behavioural outcomes. Biomarkers were recorded separately. Adverse effects were not recorded since we consider nature-based interventions relatively low-risk interventions. We also recorded specific outcomes if a positive benefit was reported on the basis of 95% confidence intervals or a p-value of less than 0·05 (if 95% confidence intervals were not available), and recorded whether the findings were based on within-group (pre-intervention *vs* post-intervention) comparisons or between-group (intervention *vs* control group) comparisons.

For more information on the tool **WebPlotDigitizer** see https://automeris.io/WebPlotDigitizer

We planned to conduct meta-analyses for the following outcomes: systolic blood pressure, diastolic blood pressure, depression, anxiety, step counts, and time spent on physical activities. For studies that reported these outcomes, we recorded the means and standard deviations for both groups, either as changes from baseline or post-intervention measurements, whichever was available. If not provided, SDs were calculated from SEs or 95% CIs of the mean.[37] If an outcome was measured at multiple follow-ups, we selected the timepoint most often reported among all studies, to make results more comparable between studies. If an outcome was measured with multiple scales, we record the scale most often reported among all studies. In one study, metabolic equivalent of task minutes were converted to minutes spent doing moderate physical activities by dividing means and SD by a factor of four.[38] Mean changes from baseline and post-intervention means were synthesised separately in subgroup meta-analyses, and their results were pooled together in the final meta-analysis if the effect estimate was mean difference.[39] Data presented in figures were extracted using WebPlotDitigizer v4.6. Studies that provided no extractable data or insufficient data to calculate SD were excluded from the meta-analysis and presented narratively. Authors were not contacted during data collection; translation was not done for studies reported in non-English languages and these studies were therefore excluded.

Risk of bias assessment

Risk of bias assessment was conducted by one reviewer (P-YN) using the ROBINS-I tool for non-randomised studies and the ROB 2.0 tool for randomised trials.

Statistical analysis

We performed descriptive statistics (frequency and percentage) of intervention characteristics, including participant age groups, settings, activity types, and the referring institutions.

For the meta-analysis, we used DerSimonian-Laird random-effect models for all outcomes, assuming the true treatment effects would likely differ among studies due to heterogeneity in age groups, pre-existing health conditions, and intervention characteristics. Standardised mean differences were used in the meta-analysis of depression and anxiety, which were measured using various scales and interpreted on the basis of the rule of thumb (0·2 as small effect, 0·5 as moderate effect, 0·8 as large effect). For other outcomes, mean differences were used. If both mean changes from baseline and post-intervention means were reported, post-intervention means were used.[39] The I^2 statistic was computed to assess heterogeneity between studies. All analyses were conducted in Review Manager 5.4.1. To explore the benefits of interventions delivered in a mechanism consistent with nature prescriptions, we additionally conducted the following subgroup analyses: studies with health providers as the referring institutions, studies with social providers as the referring institutions, and studies with both health and social providers as the referring institutions.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. All aspects related to the conduct of this study including the views stated and the decision to publish the findings are those of the authors only.

	Inclusion	Exclusion
Participant	Any human participant	Animal studies
Intervention	An instruction by a health or social provider to patients to spend time in a nature setting, such as a park, or any programme organised by health or social institutions for their patients or clients that features nature-based interventions; these are defined as interventions that used nature-based therapy to improve health outcomes and involved exposure to a nature environment, including green spaces and blue spaces; multimodal programmes where one component is nature-based activities are eligible	Interventions aimed at only changing the environment in which people live (eg, building new green spaces, changing design, or providing facilities within green spaces or the provision of gardens, indoor vegetation, community allotments, outdoor gyms, without organising any activity); programmes requiring high levels of safety and skilled organisers (eg, wilderness adventure programmes, animal-assisted therapies, mountain hiking); simulation of nature spaces (eg, virtual reality, photos, audio records) without actual nature exposure; school and after-school curricular activities, or any interventions aimed at increasing play time without a clear nature focus
Control	No intervention or intervention taking place in a non-nature setting	No control group
Outcomes	Physical, psychological, or cognitive health, and behavioural outcomes	Studies that only measure social, economic, and financial outcomes or diet composition and dietary patterns
Study design	Randomised controlled trials; non-randomised or quasi-randomised controlled trials	Observational studies; qualitative studies; conference abstracts or proceedings; editorials; theses; letters to editors; short reports; previous quantitative and qualitative reviews
Other	..	Non-English studies

Table 1: **Eligibility criteria for study selection**

Results

We retrieved a total of 5115 records from five databases, with an additional six studies from backward or forward citation checking during screening. After excluding 493 full texts (appendix 1 pp 9–22), the final sample consisted of 92 unique studies (122 reports; figure).

The included studies were published from 1999 to 2021, with a significant drop in publication in 2019, possibly due to influences of the COVID-19 pandemic (appendix 1 pp 9–22). Most included studies are randomised controlled trials (n=66; 72%). Most studies were concentrated in high-income countries (appendix 1 p 23). The countries where most interventions took place were South Korea (n=18; 20%), the USA (n=16; 17%), and Japan (n=10; 11%). The studies examined a diverse range of age groups, mainly adults (n=59; 64%) or older adults (n=25; 27%). Only 11 studies (12%) involved participants under the age of 18 years. 11 studies (12%) specifically recruited participants with socioeconomically disadvantaged backgrounds, such as low-income families or minority ethnic groups. The most common pre-existing conditions were psychiatric disorders (schizophrenia, ADHD, etc; n=13; 14%), cardiovascular disorders (post-stroke, congestive heart failure, etc; n=12; 13%) and musculoskeletal disorders (fibromyalgia, history of falls or balancing issues, etc; n=6; 7%).

The most common concerns for risk of bias were missing outcome data (due to high rates of dropouts without explicit reasons) and bias from the measurement of outcomes (due to non-blinding nature of the study design and the subjective nature of psychological assessment scales used; appendix 2).

See Online for appendix 2

The most common settings for such nature-based therapy were forests and nature reserves (n=32; 35%), parks (n=26; 28%), small community or home gardens (n=15; 16%), or botanical gardens or allotments (n=10; 11%). Two studies (2%) also featured blue spaces such as beaches. The most common activities recommended to participants were walking in nature (n=42; 46%), farming or gardening (n=27; 29%), and relaxation activities such as meditation or breathing exercises (27; 29%), among a range of other activities (art and craft, group sports, reading or listening to music, etc). Seven studies (8%) allowed participants to freely choose their activities.[40–46]

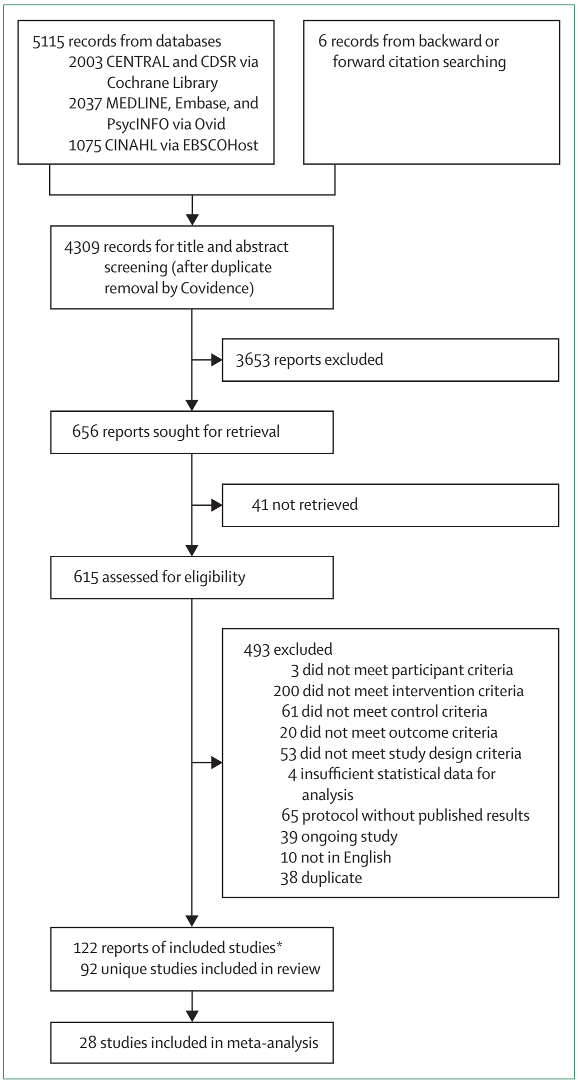

***Figure:* PRISMA flowchart of record retrieval and selection**
CDSR=Cochrane Database of Systematic Reviews. *Some studies had multiple published papers about them.

We identified 58 studies (63%) with a referring institution, who recommended, referred, or organised the intervention to participants. Only four (4%) of the 92 studies, however, self-identified as a nature or park prescription intervention.[40,42–44] Participants were commonly introduced to the programmes by their health professionals (n=29; 32%) or social professionals (29; 32%). The social service providers were diverse, and tended to be associated with pre-existing conditions of the participants (eg, day-care services or senior centres for older people in long-term care, job rehabilitation centres for people on extended sick leave, or welfare centres for low-income families). The health professionals or providers were also varied, ranging from general practitioner clinics to family health centres, post-stroke rehabilitation centres, and hospitals.

All studies featured behavioural factors from the Social Cognitive Theory framework, such as selecting activities that participants can easily carry out on their own (n=61; 66%), or providing training (n=46; 50%) or tools (37; 40%) to assist with activities (eg, gardening equipment, exercise equipment, or maps of walking paths). Most studies (n=77; 84%) featured environmental factors such as conducting activities in groups for peer support (n=52; 57%), selecting nature sites within the proximity of participants' homes, their regular health providers' offices, or the community service providers' offices (n=38; 41%). In 12 studies (13%), the authors mentioned providing measures to enable access such as transportation or free tickets for gym entry. However, cognitive factors, the third aspect of the Social Cognitive Theory, were only featured in a third of studies (n=26; 28%), such as educating participants on the benefits of nature exposure (n=18; 20%) and setting goals to motivate participants (n=17; 18%).

The panel provides summary statistics for all included studies; further details on intervention characteristics for each study are outlined in appendix 1 (pp 27–27).

Two-thirds of studies (n=62; 67%) reported benefits on psychological or cognitive outcomes. A diverse range of measurement scales were used, mainly to assess moods (eg, Profile of Mood States), depression (eg, Beck's Depression Inventory), stress (eg, Perceived Stress Scale), anxiety (eg, State-Trait Anxiety Scale), and quality of life (eg, 36-item Short-Form Survey; table 2).

39 studies (42%) reported benefits on outcomes related to physical health. Outcomes measured tended to be specific to pre-existing health conditions. For example, interventions addressing cardiovascular disorders reported benefits on cardiometabolic indicators such as blood pressures, heart rates, aerobic fitness, and bodyweight. Interventions for musculoskeletal and neurological disorders reported benefits on pain and various gross motor function tests such as the Timed Sit-to-Stand or Timed Up-and-Go tests (table 2).

23 studies (25%) reported improved behavioural outcomes, mainly time spent outdoors, time spent on moderate to vigorous physical activities, and step counts via pedometers. 11 (12%) of the 92 studies featured all three components of the Social Cognitive Theory framework (appendix 1, pp 24–27).

20 studies (22%) measured various biomarkers, mainly indicators of stress (eg, salivary cortisol) and inflammatory responses (eg, cytokines) and components of the haemodynamic control system (eg, endothelin-1, AT1 receptors; table 2).

Of the 92 studies, 28 studies contributed data to meta-analyses. 16 studies examined the outcomes eligible for meta-analysis, but were excluded from meta-analysis due to insufficient data (n=5), data provided in formats incompatible with meta-analyses (n=7), crossover trials without data from paired analysis (n=3), and unclear sample size (n=1; appendix 3).

Panel: **Study characteristics and their frequency**

Study design
Randomised controlled studies (66; 72%)
Non-randomised controlled studies (26; 28%)

Study location
South Korea (18; 20%)
USA (16; 17%)
Japan (10; 11%)
UK (7; 8%)
China (5; 5%)
Other (36; 39%)

Participant characteristics
Age group
Children, aged less than 10 years (9; 10%)
Adolescents, aged 10–18 years (2; 2%)
Adults, aged 18–65 years (59; 64%)
Older people, aged more than 65 years (25; 27%)

Social background of participants
University students (16; 17%)
Socioeconomically disadvantaged (11; 12%)
Military members (2; 2%)
Office workers (2; 2%)
Long-term care residents (2; 2%)
No specific background (59; 64%)

Underlying health conditions
Psychiatric disorders (13; 14%)
Cardiovascular disorders (12; 13%)
Musculoskeletal disorders (6; 7%)
Cancer (4; 4%)
Neurological disorders (4; 4%)
Sexual ill-health (2; 2%)
Respiratory disorders (1; 1%)
Substance use disorder (1; 1%)

Intervention characteristics
Identified as nature or green prescription (4; 4%)

Setting of nature-based therapy
Forests and nature reserves (32; 35%)
Parks (26; 28%)
Small gardens, such as at home, a nursing home, or a community centre (15; 16%)
Botanical gardens (10; 11%)
Farms (5; 5%)
Other urban green spaces (5; 5%)
Greenhouses (2; 2%)
Beaches (2; 2%)

Activities done by participants
Walking (42; 46%)
Farming or gardening (27; 29%)
Mindfulness and relaxation (25; 27%)
Other physical exercises (23; 25%)
Group games, including sports (7; 8%)
Art and craft (4; 4%)
Socialising activities, including dance (3; 3%)
Enjoying nature and relaxation (2; 2%)
Listening to music (1; 1%)
Any activity chosen by participants (7; 8%)

Institutions introducing participants to intervention
Health providers (27; 29%)
Welfare and community service providers (24; 26%)
Employers (4; 4%)
Probation service centres (2; 2%)
Long-term care providers (2; 2%)
Schools (2; 2%)

Factors influencing behavioural change featured in intervention
Behavioural factors (92; 100%)
Participants able to carry out activities on their own (61; 66%)
Training provided (46; 50%)
Tools provided (37; 40%)

Environmental factors (77; 84%)
Activities conducted in groups (52; 57%)
Nature sites accessible to participants (38; 41%)
If nature sites not accessible, measures in place to enable access (12; 13%)
Cognitive factors (26; 28%)
Informing participants on benefits of nature exposure (18; 20%)
Setting goals for participants (17; 18%)

Outcomes measured
Physical health outcomes (39; 42%)
Psychological and cognitive outcomes (62; 67%)
Behavioural outcomes (23; 25%)
Biomarkers (20; 22%)

11 randomised controlled trials (RCTs) and four non-randomised studies (NRSs) contributed data to the meta-analyses of depression and anxiety (table 3, appendix 1 p 28). The follow-up time ranged from 2 weeks to 1 year from baseline, except for one study[76] that followed up within 2 days from baseline. The most frequently used tools were the Beck Depression Inventory (n=5) for depression and the State-Trait Anxiety Inventory (n=4) or Hospital Anxiety and Depression Scale (n=4) for anxiety.

Compared with control conditions, nature-based interventions had a moderate effect on depression scores (post-intervention values standardised mean difference –0·50 [–0·84 to –0·16], I^2=83%; change from baseline standardised mean difference –0·42 [–0·82 to –0·03], I^2=0%). Nature-based interventions also had a moderate to large effect on anxiety scores (post-intervention values standardised mean difference –0·57 [–1·12 to –0·03], I^2=91%; change from baseline standardised mean difference

	Study design	Sample size	Social background	Underlying health conditions	Age group*	Mean age (SD)	% female participants and % male participants	Outcomes with reported significant† within-group positive effects (post intervention)‡	Outcomes with reported significant† positive effects compared with a control group‡
Ameli et al (2021)[47]	RCT	12	Military service members	··	Adults	35 (12)	75%; 25%	··	P: post-walk distress score, post-walk mindfulness score
Arbillaga-Etxarri et al (2017)[48]	RCT	407	··	COPD	Adults	69 (8)	13%; 87%	H: severe COPD exacerbation in previous 12 months, health-related quality of life; P: Hospital Anxiety and Depression Scale (depression); BH: clinical visit-PROactive Physical Activity in COPD	BH: daily step counts
Baba et al (2021)[49]	RCT	78	Long-term care residents	··	Older people	84 (6)	65%; 35%	H: Timed Up-and-Go test; BH: daily step counts	··
Ballew and Omoto (2018)[50]	RCT	100	University students	··	Adults	19 (2)	55%; 45%	··	P: absorption, awe, positive emotions
Bang et al (2017)[38]	NRS	99	University students	··	Adults	24 (4)	54%; 46%	H: SBP, low-density lipoprotein, triglyceride, bone density	H: percentage body fat, parasympathetic nerve activity; P: BDI; BH: weekly MET-minutes, health promoting behaviours (physical activities, healthy nutrition, stress management)
Bang et al (2018)[51]	NRS	59	Low-income families	··	Children	12 (1)	58%; 42%	P: self-esteem; Children's Depression Inventory	··
Barton et al (2012)[52]	NRS	53	··	Mental health conditions	Adults	53 (15)	62%; 38%	P: self-esteem	P: POMS (total mood disturbance)
Barton et al (2015)[53]	NRS	52	Low-income families	··	Children	9 (0)	NR	P: self-esteem BH: Minutes of moderate physical activity minutes during lunch break	··
Bielinis et al (2021)[54]	RCT	22	University students	··	Adults	23 (5)	50%; 50%	··	P: POMS, Positive and Negative Affect Schedule, Restorative Outcome Scale, Subjective Vitality Scale
Brown et al (2014)[55]	RCT	94	Office workers	··	Adults	42 (11)	20%; 80%	H: DBP, heart rate (resting, stress, and recovery), HRV; BH: Number of active lunch times, daily step counts	H: SBP; P: SF-8 mental health survey
Calogiuri et al (2016)[56]	RCT	14	Employees	··	Adults	49 (8)	50%; 50%	··	BM: serum cortisol; P: Perceived Restorativeness Scale, Physical Activity Affective Scale
Chun et al (2017)[57]	RCT	59	··	Post-stroke	Older people	61 (9)	32%; 68%	··	BM: biological antioxidant potential ; P: BDI, Hamilton Rating Scale for Depression (17 questions), State-Trait Anxiety Inventory
Cimprich and Ronis (2003)[58]	RCT	120	··	Breast cancer	Adults	54 (11)	100%; 0%	P: total attention tests' score	··
Clutterbuck et al (2020)[59]	RCT	54	··	Cerebral palsy	Children	9 (2)	35%; 65%	H: sprint test, muscle power sprint test, standing broad jump	H: Test of Gross Motor Development, Modified Canadian Occupational Performance Measure
Cohen et al (2017)[60]	RCT	1445	··	··	NR	43 (··)	62%; 38%	··	BH: participation in park programmes
Corazon et al (2018)[61]	NRS	20	··	Binge eating disorder	Adults	47 (··)	94%; 6%	P: self-esteem; BH: binge eating episodes	··
Dağistan Akgöz and Gözüm (2020)[62]	RCT	22	··	Moderate cardiovascular risks	Adults	NR	NR	H: DBP, weight, BMI, waist circumference	H: cardiovascular disease risk, total cholesterol, SBP
de Bloom et al (2017)[63]	RCT	153	Knowledge-intensive workers	··	Adults	47 (10)	90%; 10%	P: restoration; fatigue; relaxation; detachment (with seasonal effects)	··

(Table 2 continues on next page)

	Study design	Sample size	Social background	Underlying health conditions	Age group*	Mean age (SD)	% female participants and % male participants	Outcomes with reported significant† within-group positive effects (post intervention)‡	Outcomes with reported significant† positive effects compared with a control group‡
(Continued from previous page)									
de Brito et al (2020)[64]	NRS	24	··	··	Adults	50 (7)	83%; 17%	H: SBP	H: HRV
Demark-Wahnefried et al (2018)[65]	RCT	46	··	Cancer survivors	Older people	70 (8)	70%; 20%	H: waist circumference, 2-minute Step Test, Timed 8-foot Walk, 8-foot Get-Up-And-Go test; BM: telomerase; BH: vegetable & fruit intake	H: SF-36 physical health survey; P: reassurance of worth, SF-36 mental health survey
Detweiler et al (2015)[66]	RCT	24	Veterans	Substance use disorder	Adults	46 (12)	4%; 96%	P: Quality of Life Enjoyment & Satisfaction Questionnaire Short Form, Post-traumatic Stress Disorder Checklist Civilian Version, Center for Epidemiologic Studies Depression Scale	··
Djernis et al (2021)[67]	RCT	60	University students	Stress	Adults	31 (8)	87%; 13%	··	P: Self-Compassion Scale, Five-Facet Mindfulness Questionnaire, Connectedness to Nature Scale at 3 months
Elsey et al (2018)[68]	NRS	134	Probationers	··	Adults	33 (··)	29%; 71%	No significant results	No significant results
Finkelstein et al (2013)[69]	RCT	147	··	··	Children	8 (2)	46%; 54%	BH: 6-minute Walk Test	BH: Daily step counts
Finnanger Garshol et al (2020)[70]	NRS	136	Day care users	Dementia	Older people	74 (7)	59%; 41%	P: clinical dementia rating; BH: Daily step counts, Daily light and medium physical activity minutes	H: Timed Up-and-Go test
Flowers et al (2018)[71]	RCT	60	University students	··	Adults	20 (4)	32%; 68%	··	P: POMS-Vigour
Frühauf et al (2016)[72]	NRS	14	··	Depression	Adults	32 (11)	57%; 43%	··	P: Mood Survey Scale, perceived activation
Gascon et al (2020)[73]	RCT	12	··	··	Adults	37 (13)	75%; 25%	No significant results	No significant results
Gladwell et al (2016)[74]	RCT	13	··	··	Adults	39 (14)	46%; 54%	··	H: HRV
Grazuleviciene et al (2015)[75]	RCT	20	··	Coronary artery disease	Older people	62 (13)	35%; 65%	H: SBP, DBP	H: short-term SBP and heart rate recovery post-exercise
Han et al (2016)[76]	NRS	61	··	Chronic widespread pain	Adults	42 (7)	57%; 43%	H: pain VAS; P: BDI	H: HRV; BM: natural killer cells; P: EuroQol-VAS
Han et al (2018)[77]	RCT	28	··	Mental health conditions	Older people	80 (3)	86%; 14%	H: Senior Fitness Test; BM: salivary cortisol	··
Heilmayr and Friedman (2020)[78]	RCT	138	University students	··	Adults	21 (3)	69%; 31%	H: Self-reported health composite score; P: Emotional wellbeing composite score BH: Stanford Leisure-Time Activity Categorical Item	··
Hoffman et al (2018)[79]	RCT	100	Ethnic minority	Overweight, obesity	Children	9 (2)	53%; 57%	··	H: reduction in BP category at 6 months; P: social avoidance at 3 months; BH: sugar-sweetened beverage intake at 6 months, Physical Activity Questionnaire at 3 and 6 months
Jeon et al (2021)[80]	NRS	50	Probationers	··	Adolescents	16 (··)	6%; 94%	··	H: HRV; P: Well-Being Manifestation Measure Scale
Kam and Siu (2010)[81]	RCT	24	··	Mental health conditions	Adults	44 (12)	29%; 71%	··	P: Depression Anxiety Stress Scale
Kang et al (2021)[82]	RCT	33	Sibling of children with disability	··	Children	9 (2)	38%; 62%	H: brain function quotients; P: Han's Stress Scale, Self-esteem Scale	··

(Table 2 continues on next page)

	Study design	Sample size	Social background	Underlying health conditions	Age group*	Mean age (SD)	% female participants and % male participants	Outcomes with reported significant† within-group positive effects (post intervention)‡	Outcomes with reported significant† positive effects compared with a control group‡
(Continued from previous page)									
Kim and Park (2018)[83]	RCT	36	··	··	Adults	NR	100%; 0%	P: Self-rated Depression Scale, State-Trait Anxiety Inventory, Ego-identify scale	··
Kim et al (2018)[84]	RCT	47	··	··	Older people	73 (5)	91%; 9%	H: weight, BMI, lean mass, % body fat, waist circumference; BM: blood glucose	H: fitness tests; BM: insulin levels, Homeostatic Model Assessment for Insulin Resistance, chemerin
Kim et al (2021)[85]	RCT	38	University students	··	Adults	22 (2)	37%; 63%	P: POMS, Stress Response Inventory-Modified Form, Concise Measure of Subjective Well-being	··
Kobayashi et al (2018)[86]	RCT	520	University students	··	Adults	22 (2)	0%; 100%	··	H: HRV
Koselka et al (2019)[87]	NRS	24	University students	··	Adults	23 (5)	47%; 53%	··	P: PNAS, State-Trait Anxiety Inventory, PSS
Lacharité-Lemieux et al (2015)[88]	RCT	23	··	Post-menopausal	Adults	60 (5)	100%; 0%	BM: BDI; BH: Physical Activity Scale for the Elderly	··
Lee and Lee (2014)[89]	RCT	70	··	··	Older people	70 (5)	100%; 0%	··	H: SBP, DBP, pulmonary function, cardio-ankle vascular index
Leiros-Rodríguez and García-Soidan (2014)[90]	RCT	28	··	Balance issues	Older people	69 (3)	100%; 0%	P: SF-12 health survey	··
Li et al (2016)[91]	RCT	19	··	··	Adults and Older people	51 (9)	0%; 100%	··	H: pulse rate; BM: noradrenaline, dopamine, adiponectin; P: POMS
Liu et al (2020)[92]	RCT	42	··	··	Older people	69 (5)	71%; 29%	No significant results	No significant results
Makizako et al (2019)[93]	RCT	89	··	Dementia, depression	Older people	73 (6)	51%; 49%	BM: serum brain-derived neurotrophic factor; P: Geriatric Depression Scale-15; BH: daily step counts (decreased), daily moderate physical activity minutes	P: logical memory scores
Mao et al (2012a)[94]	RCT	20	University students	··	Adults	21 (1)	0%; 100%	··	BM: IL-6, tumour necrosis factor-α, malondialdehyde, total B cells, endotheline-1, serum cortisol; P: POMS
Mao et al (2012b)[95]	RCT	24	··	Hypertension	Older people	68 (4)	NR	H: SBP, DBP; BM: angiotensin II type 2, IL-6	H: SBP, DBP; BM: endotheline-1, angiotensinogen, angiotensin II type 1 ; P: POMS
Mao et al (2017)[96]	RCT	33	··	Congestive heart failure	Older people	73 (6)	42%; 58%	BM: angiotensin II type -2	BM: endotheline-1, IL-6, malondialdehyde, brain natriuretic peptide, total superoxide dismutase; P: POMS
McEwan et al (2019)[40]	NRS	582	··	··	Adults	29 (10)	60%; 40%	P: Recovering Quality of Life scale, Inclusion of Nature with Self scale, Type of Positive Affect scale, Nature Relatedness scale	··
Miller et al (2021)[97]	NRS	19	··	Cancer survivors	Adolescents; Adults	20 (··)	53%; 47%	No significant results	No significant results
Mohamed et al (2018)[98]	NRS	61	··	Overweight, obesity	Adults	46 (9)	79%; 21%	H: % body fat	H: BMI, body weight; BH: vegetable intake, calorie intake, weekly MET minutes
Morris et al (2021)[41]	NRS	178	··	Cancer patients	Adults	60 (12)	72%; 28%	··	H: aerobic fitness
Müller-Riemenschneider et al (2020)[42]	RCT	160	··	··	Adults	51 (6)	79%; 21%	··	BH: weekly minutes of recreational physical activity

(Table 2 continues on next page)

	Study design	Sample size	Social background	Underlying health conditions	Age group*	Mean age (SD)	% female participants and % male participants	Outcomes with reported significant† within-group positive effects (post intervention)‡	Outcomes with reported significant† positive effects compared with a control group‡
(Continued from previous page)									
Ng et al (2018)[99]	RCT	59	··	··	Older people	67 (5)	79%; 21%	BM: serum IL-6, serum brain-derived neurotrophic factor; P: Scales of Psychological Well-being, Zung Self-Rating Anxiety Scale	··
Ngo et al (2014)[100]	RCT	285	··	··	Children	8 (2)	46%; 54%	··	BH: weekly outdoor time
Oh et al (2018)[101]	NRS		··	Schizophrenia	Adults	42 (13)	29%; 71%	P: Positive and Negative Syndrome Scale	··
Pálsdóttir et al (2019)[102]	RCT	101	··	Post-stroke	Older people	66 (··)	60%; 40%	H: Modified Rankin Scale; P: Mental Fatigue Scale, Hospital Anxiety and Depression Scale	··
Park et al (2010)[103]	RCT	280	University students	··	Adults	22 (2)	0%; 100%	··	H: pulse rate, SBP, DBP, HRV; BM: salivary cortisol
Park et al (2020a)[104]	NRS	40	··	··	Older people	72 (5)	65%; 35%	H: hand dexterity test	P: Mini Mental State Examination
Park et al (2020b)[105]	RCT	53	··	··	Adults	NR	100%; 0%	BM: serum serotonin	··
Payne et al (2020)[43]	RCT	200	University students	··	Adults	31 (12)	82%; 18%	P: Maslach Burnout Inventory, Satisfaction with Life Scale	P: PSS
Plotnikoff et al (2017)[106]	RCT	84	··	Overweight, obesity; type 2 diabetes, high risk of diabetes	Adults	45 (14)	70%; 30%	··	H: aerobic fitness at 10 weeks, lower body muscular fitness, functional mobility, upper body muscular fitness, waist circumference and SBP at 10 weeks and 20 weeks; BH: daily step counts at 10 weeks
Razani et al (2018)[44]	RCT	78	Parents in low-income neighbourhoods	··	Adults & children	38 (··)	87%; 13%	BM: serum cortisol at 3 months; P: PSS-10 at 1 and 3 months, loneliness at 1 and 3 months, nature affinity at 3 months; BH: park visits at 1 month, weekly minutes of moderate physical activity at 1 and 3 months	··
Ryu et al (2020)[107]	RCT	60	··	Schizophrenia	Adults	39 (10)	47%; 53%	P: Rosenberg Self-Esteem Scale	P: Brief Psychiatric Rating Scale, BDI, State-Trait Anxiety Inventory, Global Assessment of Functioning Scale, Wisconsin Card Sorting Test for executive function, Rosenberg Self-Esteem Scale; BH: daily step counts
Sales et al (2017)[108]	RCT	66	··	History of falls	Older people	71 (7)	67%; 33%	··	H: single leg stance, knee strength, 2-min walk, Timed Sit-to-Stand
Serrat et al (2020)[109]	RCT	169	··	Fibromyalgia	Adults	54 (9)	99%; 1%	··	H: fibromyalgia impact questionnaire revised, VAS-Fatigue, VAS-Pain; P: Hospital Anxiety and Depression Scale, SF-36 survey, Positive and Negative Affect Schedule
Shin (1999)[110]	NRS	27	··	··	Older people	NR	100%; 0%	··	H: maximal oxygen consumption, forced vital capacity, SBP, DBP, flexibility; P: POMS
Siu et al (2020)[111]	RCT	82	··	Mental health conditions	Adults	50 (10)	55%; 45%	··	P: Short Warwick—Edinburgh Mental Well-Being Scale
Song et al (2013)[112]	RCT	485	University students	··	Adults	22 (2)	0%; 100%	··	H: DBP, pulse rate
Song et al (2019)[113]	RCT	12	University students	··	Adults	21 (1)	100%; 0%	··	H: HRV, heart rate; P: POMS

(Table 2 continues on next page)

	Study design	Sample size	Social background	Underlying health conditions	Age group*	Mean age (SD)	% female participants and % male participants	Outcomes with reported significant† within-group positive effects (post intervention)‡	Outcomes with reported significant† positive effects compared with a control group‡
(Continued from previous page)									
South et al (2021)[45]	RCT	36	Ethnic minority; low-income neighbourhoods	Postpartum	Adults	28 (6)	100%; 0%	··	BH: number of green space visits (as-treated analysis only)
Stigsdotter et al (2018)[114]	RCT	84	Sick leave	Adjustment disorders; severe stress	Adults	48 (8)	76%; 24%	P: Psychological General Well-Being Index, Shirom–Melamed Burnout Questionnaire	··
Sung et al (2012)[115]	NRS	56	··	Hypertension	Older people	66 (7)	39%; 61%	H: SBP	BM: salivary cortisol; P: SF-36 survey
Takayama et al (2014)[116]	RCT	45	University students	··	Adults	21 (1)	0%; 100%	··	P: POMS, Positive and Negative Affect Schedule
Tharrey et al (2020)[117]	NRS	132	··	··	Adults	44 (14)	76%; 24%	No significant results	No significant results
Turner and Stevinson (2017)[118]	RCT	22	··	··	Adults	33 (9)	36%; 64%	··	P: affective responses, Subjective Vitality Scale
Ura et al (2020)[119]	NRS	29	··	Dementia	Older people	76 (10)	NR	··	P: WHO-5 Well-Being Index
van den Berg and Custers (2011)[120]	RCT	30	··	··	Adults	58 (··)	73%; 27%	BM: salivary cortisol	P: Positive and Negative Affect Schedule
van den Berg and van den Berg (2011)[121]	NRS	12	··	Attention-deficit hyperactivity disorder	Children	13 (2)	17%; 83%	··	P: Perceived Restorativeness Scale, Test of Everyday Attention for Children
Verra et al (2012)[122]	NRS	79	··	Chronic musculoskeletal pain	Adults	NR	NR	H: SF-36 survey (physical role and bodily pain), Back Performance Scale; P: SF-36 survey (mental), West Haven-Yale Multidimensional Pain Inventory-Life control	··
Vujcic et al (2017)[123]	RCT	30	··	Psychiatric disorders	Adults	45 (10)	70%; 30%	··	P: Depression Anxiety Stress Scale
Wang et al (2018)[124]	RCT	28	University students	··	Adults	NR	32%; 68%	··	BM: urinary hydrogen peroxide, urinary 8-hydroxy-20-deoxyguanosine
Wexler et al (2021)[46]	RCT	171	··	··	Adults	NR	NR	BH: park visits, park-based physical activity minutes	··
Wichrowski et al (2005)[125]	RCT	107	··	Cardiac rehabilitation patients	Adults	NR	39%; 61%	H: heart rate; P: POMS	··
Willert et al (2014)[126]	NRS	93	Sick leave	Stress-related symptoms	Adults	NR	83%; 17%	P: PSS, Basic Nordic Sleep Questionnaire, Five Facet Mindfulness Questionnaire, Self-efficacy Scale, self-assessed work ability	··
Wong et al (2021)[127]	RCT	59	··	··	Older people	67 (4)	78%; 22%	BM: $CD8^+$ T cells, $CD8^+$ memory T cells re-expressing CD45RA cells	··
Wu et al (2020)[128]	RCT	31	··	Hypertension	Older people	74 (6)	39%; 61%	H: heart rate	H: DBP, pulse oxygen saturation, HRV; BM: High-sensitive C-reactive protein; P: POMS
Yi et al (2021)[129]	NRS	69	··	··	Older people	75 (5)	52%; 48%	H: electroencephalogram	H: bioimpedance
Zhu et al (2016)[130]	RCT	110	··	Schizophrenia	Adults; older people	47 (9)	44%; 56%	··	P: Positive and Negative Syndrome Scale

BDI=Beck Depression Inventory. COPD=chronic obstructive pulmonary disease. DBP=diastolic blood pressure. HRV=heart rate variability. MET=metabolic equivalent of task. NR=not reported. NRS=non-randomised studies (non-randomised controlled trials and quasi-experimental studies). POMS=Profile of Mood States. PSS=Perceived Stress Scale. RCT=randomised controlled trials. SBP=systolic blood pressure. SF=Short Form. VAS=visual analogue scale. *Children: ages <10 years; adolescent: ages 10–18 years; adults: ages 18–65 years; older people: ages >65 years old. †Statistical significance at α=0·05.‡H: Physical health outcomes; BM: Biomarkers; P: Psychological, cognitive, and quality of life outcomes; BH: Behavioural outcomes.

Table 2: **Summary of study designs and findings**

	Type of effect measure	Mean change from baseline			Post intervention mean			Overall*		
		n studies (sample size)	Effect estimate (95% CI)	I^2	n studies (sample size)	Effect estimate (95% CI)	I^2	n studies (sample size)	Effect estimate (95% CI)	I^2
All studies (n=28)										
Anxiety	SMD	1 (22)	–1·27 (–2·20 to –0·33)	NA	7 (707)	–0·57 (–1·12 to –0·03)	91%	NA	NA	NA
Depression	SMD	3 (102)	–0·42 (–0·82 to –0·03)	0%	12 (954)	–0·50 (–0·84 to –0·16)	83%	NA	NA	NA
SBP, mm Hg	MD	5 (268)	–5·38 (–11·23 to 0·47)	66%	4 (173)	–4·40 (–11·25 to 2·46)	61%	9 (441)	–4·82 (–8·92 to –0·72)	60%
DBP, mm Hg	MD	5 (268)	–4·16 (–9·46 to 1·14)	72%	4 (173)	–3·21 (–5·83 to –0·59)	38%	9 (441)	–3·82 (–6·47 to –1·16)	59%
Daily step count, 1000s of steps	MD	1 (84)	1·33 (0·10, 2·56)	NA	5 (659)	0·89 (0·78 to 1·01)	0%	6 (743)	0·90 (0·79 to 1·01)	0%
Weekly moderate physical activity, minutes	MD	NA	NA	NA	5 (472)	25·90 (–10·26 to 62·06)	53%	NA	NA	NA
Health providers as referring institutions (n=12)										
Anxiety	SMD	NA	NA	NA	4 (541)	–0·07 (–0·52 to 0·38)	84%	NA	NA	NA
Depression	SMD	1 (51)	–0·42 (–0·97 to 0·14)	NA	5 (570)	–0·34 (–0·65 to –0·03)	64%	NA	NA	NA
SBP, mm Hg	MD	4 (222)	–7·64 (–12·84 to –2·44)	33%	1 (19)	–12·90 (–24·73 to –1·07)	NA	5 (241)	–8·30 (–12·87 to –3·73)	23%
DBP, mm Hg	MD	4 (222)	–5·84 (–11·35 to –0·32)	61%	1 (19)	–6·40 (–14·46 to 1·66)	NA	5 (241)	–6·01 (–10·38 to –1·63)	48%
Daily step count, 1000s of steps	MD	1 (84)	1·33 (0·10 to 2·56)	NA	2 (293)	1·38 (0·40 to 2·35)	0%	3 (377)	1·36 (0·59 to 2·12)	0%
Weekly moderate physical activity, minutes	MD	NA	NA	NA	1 (42)	52·90 (33·72 to 72·08)	NA	NA	NA	NA
Social providers as referring institutions (n=10)										
Anxiety	SMD	1 (22)	–1·27 (–2·20 to –0·33)	NA	2 (95)	–1·91 (–2·40 to –1·42)	0%	NA	NA	NA
Depression	SMD	1 (22)	–0·88 (–1·77 to 0·00)	NA	5 (307)	–0·93 (–1·79 to –0·07)	92%	NA	NA	NA
SBP, mm Hg	MD	1 (46)	1·50 (–3·58 to 6·58)	NA	1 (99)	0·90 (–3·89 to 5·69)	NA	2 (145)	1·18 (–2·30 to 4·67)	0%
DBP, mm Hg	MD	1 (46)	1·00 (–3·50 to 5·50)	NA	1 (99)	–0·50 (–3·53 to 2·53)	NA	2 (145)	–0·03 (–2·54 to 2·48)	0%
Daily step count, 1000s of steps	MD	1 (78)	0·91 (0·62 to 1·20)	NA	NA	NA	NA	NA	NA	NA
Weekly moderate physical activity, minutes	MD	NA	NA	NA	3 (376)	23·41 (–7·69 to 54·50)	0%	NA	NA	NA
Both health and social providers as referring institutions (n=22)										
Anxiety	SMD	1 (22)	–1·27 (–2·20 to –0·33)	NA	6 (636)	–0·62 (–1·26 to 0·02)	93%	NA	NA	NA
Depression	SMD	3 (102)	–0·42 (–0·82 to –0·03)	0%	10 (877)	–0·58 (–0·97 to –0·20)	85%	NA	NA	NA
SBP, mm Hg	MD	5 (268)	–5·38 (–11·23 to 0·47)	66%	2 (118)	–4·90 (–18·25 to 8·45)	78%	7 (386)	–4·88 (–9·63 to –0·13)	65%
DBP, mm Hg	MD	5 (268)	–4·16 (–9·46 to 1·14)	72%	2 (118)	–2·22 (–7·47 to 3·04)	45%	7 (386)	–3·64 (–7·35 to 0·07)	67%
Daily step count, 1000s of steps	MD	1 (84)	1·33 (0·10 to 2·56)	NA	3 (371)	0·95 (0·67 to 1·22)	0%	4 (455)	0·96 (0·69 to 1·23)	0%
Weekly moderate physical activity, minutes	MD	NA	NA	NA	4 (418)	39·07 (12·55 to 65·59)	32%	..	..	..

DBP=diastolic blood pressure. MD=mean difference. NA=not applicable. SBP=systolic blood pressure. SMD=standardised mean difference. *Subgroup analyses with mean change from baseline and post intervention means were not combined and therefore reported separately for outcomes using SMD (ie, anxiety and depression scores).

Table 3: **Meta-analysis results**

–1·27 [–2·20 to –0·33]). For depression scores, subgroup analysis restricted to studies featuring a referring institution (n=12) showed no difference in mean change from baseline and stronger effects in post-intervention means (standardised mean difference –0·58 [–0·97 to –0·20], I^2=85%) than in the general analysis. For anxiety scores, stronger effects were also observed in post-intervention means (standardised mean difference –0·62 [–1·26 to 0·02], I^2=93%) than in the general analysis; however, the results are uncertain, with the 95% confidence interval including the null. Further stratified analyses by type of referring institutions showed that strong effects on reducing anxiety and depression scores were observed mainly in studies featuring social professionals but not health professionals (table 3).

Four other studies, comprising three RCTs and one NRS, were not included in the meta-analysis (appendix 3). All four studies evaluated horticulture therapies and reported that horticulture or gardening activities improved depression and anxiety symptoms among older people,[99] stroke survivors,[102] or military veterans[66] compared with baseline but did not significantly improve symptoms compared with control conditions. For psychiatric patients, Vujcic and colleagues[123]

See Online for appendix 3

reported that horticulture therapy relieved stress but not depression or anxiety.

Seven RCTs and two NRSs contributed data to the meta-analyses of systolic and diastolic blood pressure (table 3, appendix 1 p 29). The follow-up time ranged from 1 week to 12 weeks from baseline, except for one study[75] that conducted baseline and follow-up measurements within the same day.

Compared with control conditions, nature-based interventions resulted in a greater reduction in systolic blood pressure (mean difference –4·82 mm Hg [–8·92 to –0·72], I^2 60%) and diastolic blood pressure (mean difference –3·82 mm Hg [–6·47 to –1·16], I^2 59%). Subgroup analysis restricted to studies featuring a referring institution (n=7) showed similar reduction in systolic blood pressure (mean difference –4·88 mm Hg [–9·63 to –0·13], I^2=60%) and diastolic blood pressure (mean difference –3·64 mm Hg [–7·35 to 0·07], I^2 67%); however, the results for diastolic blood pressure are uncertain, with the 95% confidence interval including the null. Further stratified analyses by type of referring institutions showed that reductions in systolic and diastolic blood pressure were observed mainly in studies featuring health professionals but not social professionals (table 3).

Five other studies, comprising three RCTs and two NRSs, were not included in the meta-analysis (appendix 3). One study evaluated a clinic–community programme of organised games and sports at urban parks for children who are obese. The study reported a statistically significant decrease in percentage of children classified as high or borderline blood pressure after 6 months, but no statistically significant improvements in actual systolic blood pressure or diastolic blood pressure percentile.[79] Other studies reported that walking in forests or parks was linked to a higher decrease in systolic and diastolic blood pressure than in control conditions in older people[110] and healthy adults.[103,112] A non-randomised, cross-over trial reported improved blood pressure outcomes after walking in a green environment but the improvement was not different from walking in a suburban environment.[64]

Eight RCTs and two NRSs contributed data to the meta-analysis of physical activity (table 3, appendix 1 p 30). The follow-up time ranged from 10 weeks to 1 year from baseline.

Compared with control conditions, nature-based interventions resulted in a greater increase in daily step counts (mean difference 900 steps [790 to 1010], I^2 0%). The effect on weekly minutes of moderate physical activities was uncertain (mean difference 25·9 min [–10·3 to 62·1], I^2 53%). Subgroup analysis restricted to studies featuring a referring institution (n=8) showed slightly stronger effects on both daily step counts (mean difference 960 steps [690 to 1230], I^2 0%) and weekly minutes of moderate physical activities (mean difference 39·1 min [12·6 to 65·6], I^2=32%) than the general analysis. Further stratified analyses by type of referring institutions showed that beneficial effects on daily step counts were strong in studies featuring health professionals but uncertain in social professionals (table 3).

Six other studies, comprising three RCTs and three NRSs, were not included in the meta-analysis (appendix 3). One study showed that office workers taking lunch walks in a natural environment were more likely to achieve target step counts than those in a built environment.[55] Similar benefits were observed in a community gardening programme for adults who are obese[98] or a farm-based day care for patients with dementia.[70] In a study of cancer survivors, however, outdoor exercises did not have greater effect on long-term physical activity than indoor exercises.[97] Among school students, nature-based activities did not increase moderate physical activity during play time more than activities not based in green spaces.[53] Razani and colleagues[44] reported that, compared with park prescription alone, additional support in the form of text reminders and invitation to group nature outings resulted in a significant increase in park visits but not in moderate physical activity.

Discussion

High rates of interest in nature prescriptions are a response to challenges in health care caused by COVID-19 and our ongoing climate crisis.[131–134] Our systematic review identified a range of nature-based interventions that were implemented in a manner consistent with nature prescription programmes. These interventions were shown to be effective for various age groups, including children and older individuals, and targeted various health conditions, such as cardiovascular conditions, musculoskeletal disorders, and psychiatric disorders. In addition, meta-analyses on key outcomes showed benefits to blood pressure, symptoms of depression and anxiety, and physical activity rates. This result aligns with findings from studies on the effects of the nature environment on cardiometabolic health[10] and mental health.[27] Subgroup analyses suggest that these positive effects are stronger in studies where the interventions were recommended or organised by a health or social professional with an existing connection to patients.

The following key observations were made after examining the characteristics of these interventions, which can inform design of future nature prescription programmes. First, these nature prescription programmes took place across diverse nature settings, including both green spaces and blue spaces. Green spaces can be urban landscape such as parks, forests and hills, or nature environments tailored to the activities, such as farms and gardens for horticulture, or lakes and seas for outdoor swimming and other blue space-based activities. Second, nature prescription programmes can use a range of different activities to suit the health conditions of the participants. Many of the studies included multimodal interventions that coupled a physical activity (eg, walking or gardening) with a relaxation activity (eg, meditation or breathing exercises). Third, in addition to health professionals, social and community services were also effective channels to introduce participants to the intervention, especially for psychological outcomes. Some interventions were implemented as workplace programmes for office workers. Social professionals (eg, social workers) should be considered when designing future nature prescription programmes to maximise outreach and recruitment.

Our systematic review complements previous findings on nature prescriptions, which were limited to prescriptions dispensed in an outpatient setting[30] or prescriptions for mental health.[31] By using a broad scope, we captured nature-based interventions that were dispensed outside the clinic setting and did not self-label as nature prescriptions but nonetheless exhibited similar mechanisms of a prescription.

Our study was not without limitations. Since our primary aim was to conduct a systematic review on all potential nature-based interventions, our search strategy was designed to be generic. Therefore, we might have missed some studies that feature unconventional nature-based therapies. In addition, as we only included studies reported in English, we might have excluded relevant studies reported in other languages and introduced bias due to missing data, especially considering many studies are from east Asian countries (eg, South Korea or Japan). Our data collection and risk-of-bias assessment was not conducted in duplicate, which potentially introduces some subjectivity. Since the included studies did not stratify their results by demographic variables (eg, age or sex), there was insufficient data to determine the influence of sex or gender on the health effects of nature prescriptions.

Heterogeneity statistics from our meta-analysis suggest a high degree of heterogeneity in true effects among our included studies, possibly due to different target populations, nature settings, and activities featured in the intervention. Future studies are needed to examine the varying effectiveness of nature-based prescriptions based on these factors. Moreover, a comparison of effectiveness on increasing physical activity rates based on different elements of the Social Cognitive Theory, or other suitable behavioural models, will help identify factors that make a behavioural change programme successful. Most studies have moderate to high risk of bias, principally due to the non-blinding nature of the study design, small sample sizes, and a scarcity of published documentations to rule out bias, such as an a priori analysis plan or protocol. This high risk of bias calls for future efforts to enhance the standards of reporting and conduct of trials in this area of research to improve the overall quality of evidence.

Nature prescription programmes are increasing in popularity around the world. A key incentive is for nature prescription programmes to supplement the focus of health practitioners on biomedical options, by attending to health and social needs that standard care cannot reach. Our review concludes that the present evidence indicates nature prescriptions can provide positive benefits on blood pressure, symptoms of depression and anxiety, and physical activity. Nature prescriptions can feature a range of natural settings and activities. Social and community channels should be used for outreach, in addition to health professionals.

Contributors

XF and TA-B conceptualised the study, acquired funding, supervised the study, and reviewed and edited the manuscript. P-YN curated the data, did the analysis, and wrote the original draft. HR-A contributed to the analysis. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication. More than one author has directly accessed and verified the underlying data reported in the manuscript.

Declaration of interests

We declare no competing interests.

Acknowledgments

TA-B was supported by a National Health and Medical Research Council Boosting Dementia Research Leader Fellowship (1140317). XF was supported by a National Health and Medical Research Council Career Development Fellowship (1148792). All data and materials used to generate the results are available in the manuscript and appendices.

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