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Systematic review and meta-analysis investigating nature-based interventions for adolescent mental health: Program characteristics and effectiveness

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ABSTRACT

Background: Rates of psychological distress among adolescents have increased globally, alongside a marked decline in time spent in natural environments. Nature-based interventions (NBIs), structured therapeutic programs involving direct engagement with real, physical natural settings, have emerged as a potentially low-cost and scalable approach to supporting adolescent mental health. However, the characteristics and effectiveness of group-based NBIs for this population have not been comprehensively synthesised.

Methods: A systematic review and meta-analysis was conducted in accordance with PRISMA 2020 guidelines on peer-reviewed studies published between 2015 and 2025 evaluating group NBIs for adolescents aged 11–19. Eligible designs included quasi-experimental trials with a comparison group and single-group pre-post studies reporting validated psychometric outcomes of mental health or psychological distress. Random-effects meta-analysis was undertaken where possible; when data were unsuitable for pooling, findings were synthesised using Synthesis Without Meta-analysis (SWiM). Program characteristics (e.g., duration, setting, facilitator expertise, and contents) were extracted and narratively synthesised.

Discussion: Twenty-five studies met inclusion criteria. Quasi-experimental designs assessing mental health outcomes demonstrated a large, statistically significant pooled effect ($g = 0.82$, 95 % CI [0.32, 1.31]). Single-group pre-post studies showed a moderate significant improvement in mental health ($g = 0.60$, 95 % CI [0.36, 0.85]) and a small but significant reduction in psychological distress was also detected ($g = 0.28$, 95 % CI [0.04, 0.52]). Narrative synthesis of four studies suggested positive emotional and wellbeing outcomes for some adolescents although findings remain tentative due to incomplete reporting and very small samples. Effectiveness patterns suggest that multi-day immersive programs and those facilitated by practitioners with relevant clinical or specialist outdoor expertise tend to yield the largest benefits. The overall certainty of evidence was low for quasi-experimental studies and very low for pre-post and SWiM evidence.

Systematic review registration: This review was prospectively registered with PROSPERO (CRD420251033171).

1. Introduction

1.1. Background

Psychological distress during adolescence can have profound and lasting impacts on development, functioning, and overall wellbeing (World Health Organization [WHO], 2023). Characterised by symptoms such as anxiety, depression, and stress, psychological distress can interfere with cognitive, emotional, and social development (Lawrence et al., 2015). Adolescents experiencing high levels of distress are at greater risk for poor academic outcomes, substance use, social withdrawal, and the development of severe mental health disorders in adulthood (Australian Institute of Health and Welfare [AIHW], 2023). In contrast, adolescents experiencing positive mental health, defined as a state of wellbeing that enables individuals to realise their abilities, cope with the stresses of life, and contribute to their community, are more likely to experience resilience, positive affect, and social connectedness (WHO, 2022a).

Given that adolescence is a formative period marked by rapid neurobiological and psychosocial changes, early mental health

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challenges can significantly shape life trajectories and contribute to long-term health inequalities (Patton et al., 2016).

1.1.1. Mental health trends in adolescents

Over the past two decades, international data indicates a clear and concerning rise in psychological distress among adolescents (Viner et al., 2022; World Health Organization [WHO], 2022b). Large-scale reviews of global research consistently indicate rising rates of mental health challenges among young people aged 11 to 19, with a particularly sharp increase over the past decade (NHS Digital, 2022; The Children's Society, 2022). A global meta-analysis of over 80,000 adolescents found that the prevalence of depressive and anxiety symptoms doubled during the pandemic (Racine et al., 2021), while Barendse et al. (2023) reported significant increases in adolescent depression and anxiety symptoms compared to pre-pandemic levels. Pandemic-related social isolation and disruption were also associated with increased loneliness and psychological stress among adolescents (Viner et al., 2022; WHO, 2022b).

This pattern is evident across multiple countries. In the United States of America (USA), the number of high school students reporting hopelessness or persistent feelings of sadness, rose from approximately 28 % in 2011 to 42 % in 2021 (Jones et al., 2022). Similarly, in England, the proportion of children and adolescents with probable mental health disorders increased from one in nine in 2017 to one in six in 2021 (NHS Digital, 2022). Recent large-scale population reviews further suggest that these escalating rates are influenced by broader societal shifts, with increases in adolescent emotional problems linked to rising school-related stress, family poverty and inequality, as well as major lifestyle changes such as the rapid rise of digital media use, although its implications for adolescent mental health trends remain unclear (Armitage et al., 2024). These international findings highlight a persistent and escalating pattern of distress among adolescents worldwide (Barendse et al., 2023; WHO, 2022b).

1.1.2. Technology and psychological distress

This rising pattern of distress has coincided with adolescents spending more time engaging with screens. According to Common Sense Media (Rideout et al., 2022), adolescents in the USA spend a daily average of 7 h and 22 min on screens, plus additional time for schoolwork, which is equivalent to nearly 40 % of their waking hours. This trend intensified during the COVID-19 pandemic. Nagata et al. (2022) found that average recreational screen time among 12 to 13-year-olds in the USA more than doubled during the pandemic, from 3.8 h to 7.7 h per day. Similarly, the Organisation for Economic Co-operation and Development (OECD, 2025) reported that nearly all 15-year-olds (96 %) across 38 member countries (including North America, South America, Europe and Asia-Pacific) now have access to smartphones and other digital devices, highlighting how pervasive screen use is among adolescents. Excessive screen time has been associated with increased psychological distress in adolescents, particularly when daily usage exceeds 3 h (Twenge & Campbell, 2018). These findings suggest that elevated screen exposure may be a contributing factor in the global rise of adolescent mental health challenges.

With approximately one in seven adolescents aged 10–19 experiencing a mental health disorder such as anxiety or depression (WHO, 2023), a growing body of research has investigated this link, and recent systematic reviews and meta-analyses consistently report small but significant associations between screen time and psychological distress. A 2023 meta-analysis of 18 cohort studies involving 241,398 participants found that adolescents with high screen use had a 10 % greater likelihood of developing depressive symptoms (Li et al., 2022). Additionally, longitudinal studies have indicated that increases in daily screen time can predict heightened symptoms of anxiety and depression (Mougharbel et al., 2023). These findings indicate that excessive screen use may contribute to elevated psychological distress and poorer mental health outcomes. However, these correlations do not establish causation, and other contextual or individual factors may also play a role.

1.1.3. Nature-based interventions

In light of this escalating pattern of distress in young people and the problems associated with screen-based lifestyles, there is growing interest in alternative non-screen-based interventions, such as nature-based programs, that may offer protective and restorative benefits for adolescent mental health (Kil et al., 2023). Nature-based interventions (NBIs) are structured therapeutic programs that provide exposure to real, physical, natural environments, such as forests, parks, lakes, rivers, and wilderness areas as a central therapeutic mechanism (Kaplan, 1995; Wilson, 1984). These programs typically involve guided interaction with nature, combining physical activity, sensory engagement, reflective exercises, and at times, formal psychological techniques. Examples of NBIs include forest therapy, also known as "shinrin-yoku" or forest bathing, which involves mindful, guided immersion in forested environments to promote physiological and psychological relaxation (Kotera et al., 2022); adventure therapy, which may incorporate physically challenging activities (e.g., hiking, rock climbing, sailing), and debriefing counselling exercises to enhance self-efficacy and emotional resilience (Reupert & Maybery, 2002); wilderness therapy, which combines group-based expeditions in remote natural settings such as rivers and mountains, with structured therapeutic goals and reflection (Jong et al., 2022); and ecotherapy, a broad modality that integrates nature into traditional psychological interventions, such as Cognitive Behaviour Therapy or mindfulness, to enhance treatment efficacy (Roberts et al., 2019).

These programs are commonly delivered in group formats and facilitated by professionals, including psychologists, counsellors, social workers, outdoor educators, or trained mental health practitioners with experience in experiential or nature-based methodologies (Naor & Mayseless, 2021). Group-based delivery offers distinct advantages over individualised approaches, particularly from a developmental perspective. Adolescence is a key developmental stage impacted by increased susceptibility to peer influence and the increasing importance of social identity formation (Brown & Larson, 2009; Erikson, 1968). Peer groups provide a natural and normative context in which young people can explore belonging, autonomy, and identity (Arias-Pujol & Anguera, 2017). Within the adolescent developmental context, group-based interventions allow for reciprocal peer interaction and shared experiences, which can foster psychological growth in ways that are unobtainable in individualised therapies (Pingitore & Ferszt, 2017). Compared to one-to-one delivery, group settings facilitate peer feedback, social modelling, and the normalisation of difficulties, all of which have been identified as key mechanisms of change in adolescent group work (Shechtman, 2017). From an implementation standpoint, group delivery models are typically more feasible, cost-effective, and scalable than individually focused interventions, particularly in school and community contexts where demand for mental health support is substantial (Sawyer et al., 2012).

Program duration and intensity vary considerably, from brief, 90-min outdoor activities to multi-week residential or expedition-based models. While NBIs aim to enhance participants' emotional regulation, reduce symptoms of stress and anxiety, and promote overall psychological wellbeing, the methodologies employed across studies and programs are highly heterogeneous (Moll et al., 2022). There is currently a lack of consensus on core components, delivery models, and mechanisms of action, highlighting the need for further research to identify common therapeutic elements and optimise program design. NBIs may be especially suited to adolescents, as they align with developmental needs for autonomy, social interaction, and experiential learning (Leavell et al., 2019; Mitchell et al., 2024). Contexts of delivery include community-based settings, therapeutic camps, and increasingly, school environments (Loose et al., 2024).

1.1.4. Theoretical basis for NBIs

Theoretical models underpinning NBIs include the Biophilia Hypothesis (Wilson, 1984), proposing that humans have an innate

connection to nature that supports emotional health; Attention Restoration Theory (Kaplan, 1995), which suggests that natural environments restore cognitive resources depleted by sustained attention demands; and Stress Reduction Theory (SRT; Ulrich, 1983), which proposes that exposure to natural settings elicits positive affect and reduces physiological arousal. Attention Restoration Theory (ART) has been refined to highlight soft fascination, stimuli that gently capture attention without overwhelming mental capacity, as a key mechanism for cognitive recovery (Basu et al., 2019; Kaplan, 1995). While Kaplan (1995) distinguished between hard and soft fascination, noting that the former (e.g., television) fills attention and limits reflection, the latter (e.g., natural elements like rustling leaves) allows for mental space and introspection. In an online survey of 398 adults, Basu et al. (2019) found that walking in nature was perceived as softly fascinating and highly restorative, in contrast to television, which was rated as hard fascination and less restorative.

These findings suggest that nature's capacity to gently engage attention, known as soft fascination, may facilitate cognitive restoration and attentional recovery, which are components of self-regulatory functioning (Basu et al., 2019; Kaplan, 1995). Additionally, experimental studies have demonstrated that exposure to natural environments can lead to measurable physiological benefits, including reductions in cortisol levels, blood pressure, and self-reported anxiety (Lee et al., 2015; Ulrich et al., 1991). Such outcomes are increasingly relevant for adolescents, who frequently experience somatic symptoms such as fatigue, headaches, and muscle tension as manifestations of psychological distress (Münker et al., 2024).

While the Biophilia Hypothesis, ART, and SRT provide robust frameworks for understanding the individual-level benefits of nature exposure, group-based NBIs during adolescence engage shared experiences in natural environments, which can foster belonging, cooperation, and mutual support, meeting key psychosocial needs during this stage of development (Brown & Anistranski, 2020). These social processes are important not only for engagement but also for amplifying intervention benefits, as adolescents are more likely to internalise positive behaviours and attitudes when reinforced within peer groups. Additionally, group-based NBIs can incorporate elements of novelty, challenge, and collaboration, which are theorised to enhance intrinsic motivation and self-efficacy through experiential learning models (Mackenzie et al., 2018). Nature-based group activities may therefore combine restorative cognitive and physiological mechanisms with opportunities for social bonding and identity development making them particularly suited to adolescents.

1.1.5. Previous reviews

A growing body of reviews has explored the mental health benefits of NBIs, but variations in scope and methodological rigour limit their applicability. Evidence from adult populations is reported by Coventry et al. (2021) in a systematic review and meta-analysis that included interventions such as green exercise, horticultural therapy, and nature-based psychotherapy. Coventry et al. (2021) synthesised evidence from adult populations, reporting mental health benefits of NBIs such as green exercise, horticultural therapy, and nature-based psychotherapy. Interventions included both independent and group-based activities in green and blue spaces, but the review did not examine whether the group delivery format contributed to outcomes.

Studies involving adolescents have also been reviewed. Roberts et al. (2019) identified potential benefits such as improved self-esteem, stress reduction, and resilience. The review considered both group-based activities and individual approaches (e.g., walk-and-talk therapy). However, it did not assess whether outcomes differed by delivery format, limiting insight into the unique role of group processes. Additionally, conclusions were constrained by methodological weaknesses in the underlying studies, including reliance on self-report and inadequate control for confounding factors. Similarly, Tillmann et al. (2018) synthesised evidence on children and adolescents, including both group-based interventions and cross-sectional studies of individual nature exposure. While some positive associations with psychological outcomes were noted, the review did not explicitly evaluate the contribution of group dynamics to these effects. Heterogeneous designs and failure to disaggregate by age further limited adolescent-specific conclusions.

More recent scoping and systematic reviews have broadened the evidence base of NBIs. Overbey et al. (2023) considered a wide range of NBIs for vulnerable youth with no restrictions on delivery mode, type, or duration. Although the included programs were diverse, many were group-based (e.g., wilderness therapy, horticulture, care farming). Despite this, the review did not isolate or analyse the impact of group delivery, meaning that the influence of peer or collective processes remained unclear. Obeng et al. (2023) highlighted the potential of NBIs to support sustainable wellbeing linking psychological benefits with environmental, social, and economic sustainability, and aligning with holistic models. The review incorporated children, adolescents, and young adults (<35), examining interventions ranging from group-based programs to individual therapies (e.g., animal-assisted interventions). However, outcomes were not analysed by delivery format, and group dynamics were not examined. The reported benefits were broad but did not specifically pertain to programs for general-population adolescents.

1.2. Rationale for the review

Adolescence is a critical developmental period marked by rapid biological, cognitive, and social changes, during which vulnerability to psychological distress is heightened. Despite the growing interest in NBIs, the evidence base pertaining to synthesised adolescent-specific outcomes is limited. Existing reviews have tended to concentrate on adult or mixed populations and have rarely addressed the unique developmental and contextual needs of adolescents (Coventry et al., 2021; Tillmann et al., 2018).

In particular, little synthesis has been conducted regarding the structural and delivery features of NBIs most relevant to adolescents, such as program duration, frequency, group format, setting, and facilitator expertise. These factors are crucial for guiding effective implementation in schools and community settings but are often described only narratively, without comparative evaluation (Roberts et al., 2019; Tillmann et al., 2018). Moreover, outcomes of interest in studies involving adolescents have frequently centred on cognitive or educational domains, rather than directly assessing indicators of psychological distress and wellbeing (Vella-Brodrick & Gilowska, 2022).

To our knowledge, no systematic review has comprehensively examined both the effectiveness and defining characteristics of group-based NBIs for adolescents aged 11–19. This review addresses that gap, with the goal of synthesising evidence that can inform program design, guide policy translation, and support future research aimed at strengthening adolescent mental health through nature engagement.

1.3. Objective

This systematic review aims to examine the characteristics and effectiveness of group-based NBIs for adolescents aged 11–19. Adolescence is commonly defined as spanning approximately ages 10–19 by the World Health Organization, with many researchers operationalising this period as 11–19 to reflect the middle and later stages of adolescent development (Sawyer et al., 2012; World Health Organization, 2023). The review had two objectives: (1) to identify and synthesise the core components and delivery characteristics of group-based NBIs designed for adolescents; and (2) to evaluate the effectiveness of these interventions in reducing psychological distress and improving mental health outcomes. The review addressed two research questions: (A) What are the key components and defining characteristics of group-based NBIs for adolescents? and (B) How effective are these interventions in improving adolescent psychological distress and mental

health?

2. Methods

2.1. Eligibility criteria for selecting studies

The review was conducted and reported in accordance with PRISMA 2020 guidelines (Moher et al., 2015). The population of interest was adolescents aged 11–19 years. Eligible studies evaluated group-based NBIs designed to reduce psychological distress or enhance mental health. Group delivery was selected to minimise heterogeneity associated with combining individual and group formats.

For this review, NBIs were defined as structured therapeutic programs involving direct engagement with real, physical natural environments (e.g., forests, parks, rivers, oceans, wilderness) as a central component. Programs involving simulated nature, animal-assisted therapy, or interventions where nature was incidental were excluded. Eligible programs involved nature-based engagement for at least 50 % of the intervention content or duration. Interventions were not restricted by length or intensity.

Randomised controlled trials, quasi-experimental trials, and single-group pre-post studies without a comparison group were eligible. Studies were required to report quantitative pre- and post-intervention outcomes using validated psychometric instruments assessing psychological distress or mental health. Many studies reported more than one mental-health or psychological distress related outcome.

To avoid multiple effect sizes from the same sample inflating the pooled estimate, one primary mental health and one psychological distress outcome per study were selected using the following hierarchy: For psychological distress domains, priority was given to anxiety, depression, and stress measures. For positive mental health domains, priority was given to wellbeing, self-efficacy, resilience, coping, and social connectedness. Physiological outcomes were included only when accompanied by validated psychometric outcomes. Studies without quantitative data or non-validated measures were excluded. Peer-reviewed articles published between 2015 and 2025 were included to ensure results reflect the approaches and outcome measures currently used with adolescents. Eligibility criteria were established according to the PICOS framework, as shown in Table 1.

2.2. Search methods for identification of studies

With support from a librarian, we searched APA PsycINFO, Ovid MEDLINE, EMBASE, Cochrane CENTRAL, Scopus, and ERIC. Search terms related to adolescents, nature-based therapy, psychological distress, and mental health outcomes were used. Search terms are provided in Appendix A (Table A1), and full search syntax for each database is provided in Appendix B.

In addition, supplementary searching was undertaken in accordance with PRISMA-S guidance (Rethlefsen et al., 2021). Backward citation searching involved manual screening of the reference lists of all included studies, while forward citation searching involved identifying and screening records citing the included studies using Google Scholar. All records identified through citation searching were screened using the same eligibility criteria as database-identified records. The screening process was documented using a PRISMA flow diagram.

2.3. Data management and study selection

We used Covidence (Covidence Systematic Review Software, 2023) for de-duplication, screening, and data extraction. Title and abstract screening were conducted independently by three reviewers (RC, AR, VM). Conflicting votes progressed to full-text screening. All full texts were dual screened. Reasons for exclusion were recorded. Multiple reports from the same study were identified and consolidated.

Table 1
PICOS summary table.

Domain	Inclusion Criteria	Exclusion Criteria
Population	Adolescents aged 11–19 years. Studies including broader age ranges when (a) the mean sample age falls within 11–19 years, or (b) outcomes for adolescents are reported separately.	Participants outside the 11–19 age range (or mean sample age) where adolescent data cannot be disaggregated. Studies focusing exclusively on children (<11 years) or adults (>19 years).
Intervention	Group-based NBIs (≥50 % in natural settings). Programs may be structured or semi-structured, provided that therapeutic engagement with nature is a core component.	Individual-formats. Programs using <50 % nature exposure. Virtual/simulated nature (e.g., VR). Animal-assisted therapy or interventions with incidental nature only. Programs without structured sessions.
Comparator	Usual care, waitlist control, active control, no intervention, or pre-post design (single group no comparator).	Case studies, single time-point surveys.
Outcomes	Quantitative outcomes: Psychological distress or mental health measured using validated psychometric tools (e.g., DASS-21, K10, SDQ, MHC-SF).	Studies without quantitative data measuring psychological distress/mental health measures. Studies using non-validated measures. Outcomes limited to physical health, academic achievement or environmental attitudes.
Study Design	Peer-reviewed journal articles published between 2015 and 2025. Randomised controlled trials, quasi-experimental trials, and pre-post single group studies without a comparator. No language restrictions (with translation arranged where feasible).	Grey literature (e.g., reports, conference abstracts, books). Studies published before 2015. Non-peer-reviewed sources. Texts lacking English abstract/ summary at screening. Studies where translation is not feasible under copyright, licensing, or data security restrictions.

2.4. Data extraction and management

We used Covidence to manage data extraction, supported by a pre-piloted Excel template, to ensure clarity, consistency, and relevance of the collected data. The template was piloted on a sample of five studies and refined as needed to minimise errors. Data were extracted independently by the principal investigator. Any discrepancies or uncertainties were resolved through discussion with a second reviewer (AR or VM). Data extraction was guided by the PICOS framework to ensure consistency and relevance.

A Characteristics of Included Studies table and a Core Characteristics of NBIs table were generated. Missing data were requested from Arbuthnott and Sutter (2019), and Park et al. (2021), however additional data were not resolved within the three-week timeframe proposed in the protocol. Arbuthnott and Sutter (2019) had sufficient data for narrative synthesise, however Park et al. (2021), was excluded due to lack of confirmation of data and measurement validity. Primary outcomes were changes in psychological distress or mental health from baseline to post-intervention. Follow-up outcomes could not be synthesised due to substantial inconsistency in timing and incomplete reporting across studies. Effect sizes were standardised to allow comparison across tools.

2.5. Data analysis and synthesis

2.5.1. Quantitative synthesis

We synthesised quantitative data using meta-analysis in Jamovi (The Jamovi Project, 2024). Studies were grouped and meta-analysis conducted according to design, quasi-experimental, and pre-post single group studies. To ensure meaningful synthesis, meta-analyses were undertaken only when at least three studies reported on the same outcome domain using comparable measurement tools or where calculation of

SMD is feasible.

The aim was to synthesise available evidence while acknowledging heterogeneity. Where substantial clinical or methodological heterogeneity was identified (e.g., $I^2 \geq 80$ %), results were presented narratively. Effect sizes for continuous outcomes were calculated using SMD (Hedges' *g*). For pre-post single-group studies, within-group effect sizes were calculated. Meta-analyses were conducted using the Inverse Variance method for pooling SMD. A random-effects model, DerSimonian–Laird method, was applied in all analyses to account for between-study variability. Heterogeneity was assessed using the I^2 statistic and Cochran's Q test. Any differences in scale direction across studies was aligned to ensure consistency of effect estimates. All raw effect size inputs (Hedges *g*), standard errors, scoring directions, and calculation numbers are reported for transparency in Appendix C (Table C1).

In cases where meta-analysis was not possible due to insufficient data, results were synthesised systematically using Synthesis Without Meta-Analysis (SWiM) guidelines (Campbell et al., 2020). This ensured that all findings were analysed and reported in a manner consistent with best-practice standards for systematic reviews. This synthesis involves a structured summary of results, grouped by outcome domains (e.g., mental health or psychological distress), program characteristics (e.g., duration, setting, facilitator type), and direction of effects to highlight common patterns, inconsistencies, and contextual factors that may influence outcomes. This structured approach facilitates transparent interpretation of results across studies that use diverse methodologies or outcome measures.

2.5.2. Subgroup and sensitivity analyses

Subgroup analyses were planned a priori but could not be completed due to insufficient comparable studies per subgroup. Sensitivity analyses excluding small-sample studies (<30 participants) and high-risk studies did not materially change pooled effect sizes.

2.6. Risk of bias in individual studies

We assessed the risk of bias within Covidence using the ROBINS-I tool (Sterne et al., 2016) for non-randomized studies. Two reviewers independently assessed studies, with disagreements resolved through discussion.

2.7. Meta-bias(es) and certainty of evidence

We used a funnel plot to visually explore publication bias. The certainty of evidence for the primary outcomes was evaluated using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach (GRADE Working Group, 2004) across five domains (risk of bias, consistency, directness, precision, publication bias). We rated each outcome as having high, moderate, low, or very low certainty. The GRADE approach was applied to all included studies, with consideration for the differing starting points in rating evidence certainty.

2.8. Protocol deviations and amendments

Amendments to the registered protocol were minimal and reported in PROSPERO (CRD420251033171). Subgroup meta-analyses could not be performed due to insufficient comparable studies, and follow-up outcomes were not pooled due to variability in timing. Jamovi was used to calculate effect sizes and conduct meta-analyses rather than RevMan due to accessibility and reviewer expertise, without altering the planned statistical approach.

3. Results

3.1. Study Selection

A total of 1578 studies were found during the initial database and journal search, 799 of which were duplicates. Three reviewers independently screened titles and abstracts for inclusion. Studies not meeting inclusion criteria based on title and abstract were deemed non-relevant and excluded, with 43 studies evaluated for eligibility. After examining full text, including contacting two authors for additional data, 25 studies met the inclusion criteria. The screening and selection of studies were undertaken using Covidence (2023) and reported in line with PRISMA guidelines, as illustrated in Fig. 1.

3.2. Characteristics of the included studies

The 25 included studies comprised quasi-experimental studies ($n = 7$), and single-group pre–post designs ($n = 18$). All studies were published in English between 2015 and 2025. Five studies were conducted in New Zealand, three per country in the United Kingdom, United States, and Australia, two each in China and Norway, and one study each in Canada, Hong Kong, and Germany. Across all studies, there were 2725 adolescent participants and sample sizes ranged from 9 participants (Tracey et al., 2018) to 622 participants (Allan et al., 2025).

Follow-up assessments varied across the 25 studies. Eighteen assessed outcomes at baseline and immediately post-intervention only, while seven included at least one follow-up assessment. Of these, two reported short-term follow-ups at approximately four weeks, and five reported longer-term follow-ups ranging from three to twelve months. Due to heterogeneity in follow-up timing, outcome measures, and incomplete reporting, including one study where follow-up data were collected but not analysable, follow-up outcomes were not synthesised quantitatively. Attrition was inconsistently reported across studies (see Table 2, enrolled vs analysed samples); where reported, attrition ranged from minimal (<5 %; Allan et al., 2025; Dong et al., 2025; Whittington and Aspelmeier, 2018) to substantial (>30 %; Albedry et al., 2023; Hignett et al., 2018; Keller et al., 2023), with higher attrition more commonly observed at follow-up timepoints and in longer-duration programs. A summary of all included studies is in Table 2.

3.3. Characteristics of NBIs

All interventions were delivered in group-based formats and incorporated experiential engagement with natural environments. Wilderness-based programs were used in several studies, including multi-day expeditions involving hiking, canoeing, camping, and nature reflection activities. Adventure-education approaches such as ropes courses, climbing, bushcraft, sailing, team-building, and outdoor challenge tasks were commonly employed, with sailing-focused programs featuring prominently across New Zealand-based studies. Other modalities included surfing, environmental education, forest-bathing, nature-immersion, and mindfulness-based or ACT-informed outdoor therapy programs. Creative methods like song writing in wilderness settings also featured.

All programs emphasised active bodily engagement with natural settings, and many explicitly aimed to foster nature connection, resilience, and social–emotional learning. Interdisciplinary facilitation was evident across studies, with programs led by combinations of trained outdoor instructors, psychologists, health professionals, social workers, educators, and researchers. Ethical approval was consistently reported, though details regarding funding sources and participants' socioeconomic background were inconsistent, limiting conclusions about accessibility and equity. The characteristics of NBIs varied across studies and are summarised in Table D1 (Appendix D).

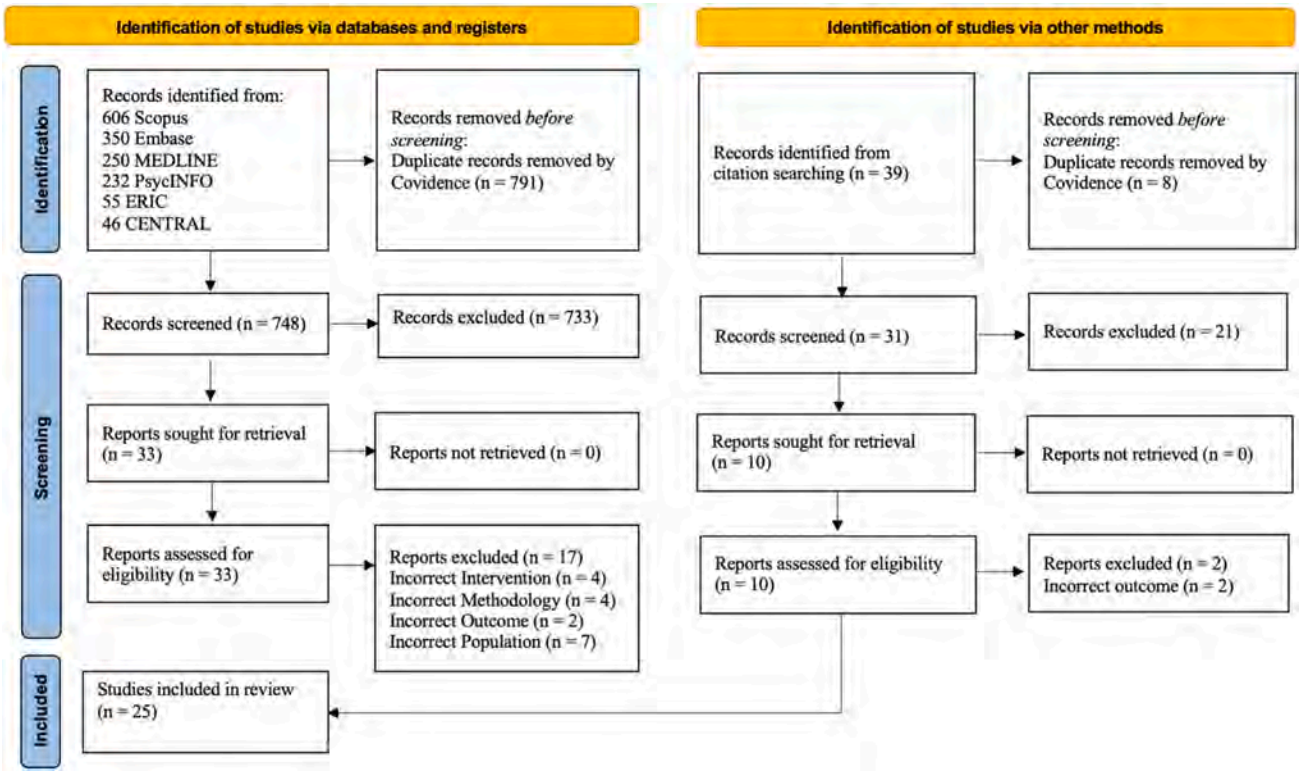

Fig. 1. Prisma flowchart of study selection.

3.4. Summary of risk of bias

Risk of bias for all included non-randomised studies was evaluated using the ROBINS-I tool (Sterne et al., 2016). Across studies, bias due to confounding was predominantly serious or critical, largely because interventions were delivered without randomisation, participants often self-selected into programs, and external influences (school context, maturation) were rarely controlled. Selection of participants was often serious, with studies relying on voluntary or referral enrolment, or inclusion criteria linked to motivation, physical ability, or clinical need. Classification of interventions generally posed a low risk. Programs were clearly described and consistently delivered; however, deviations from intended interventions were common, reflecting limited fidelity monitoring and contextual variability in delivery. Measurement of outcomes was a major source of bias, with most studies relying on unblinded self-report measures. Finally, missing data ranged from low to serious risk, with some studies experiencing substantial attrition. Overall, the studies demonstrate a serious risk of bias. While interventions were well described, methodological limitations indicate the results should be interpreted with caution. Visual summaries of the ROBINS-I assessments are presented in Fig. 2 (summary plot) and Fig. 3 (traffic light plot), created using robvis (McGuinness & Higgins, 2020).

3.5. Results of synthesis

3.5.1. Meta-analysis

Three independent meta-analyses were conducted in Jamovi (The Jamovi Project, 2024) to synthesise effect sizes from quasi-experimental and pre–post studies. Effect sizes were standardised so that positive values indicated improved mental health and where higher scores reflected greater symptom severity (e.g., depression scales), effects were multiplied by −1 to ensure a consistent direction of interpretation. Where means and standard deviations were unavailable, Hedges' g was derived from interaction effect sizes (η^2 or η_p^2), using established conversion formulas for between-group contrasts. Only time × condition interaction terms were used to estimate treatment effects; main-effect η^2 values were excluded.

The first random-effects meta-analysis, which included seven quasi-experimental studies, demonstrated a statistically significant and large pooled effect ($g = 0.82$, SE = 0.25, Z = 3.26, $p = .001$, 95 % CI [0.32, 1.31]). Heterogeneity was very high ($I^2 = 91.72$ %, $\tau^2 = 0.39$, Q(6) = 72.43, $p < .001$), indicating substantial variability in effect sizes across studies. The associated forest plot is presented in Fig. 4. The second random-effects meta-analysis, synthesising 13 pre-post mental health outcomes, revealed a statistically significant and moderate pooled effect ($g = 0.60$, SE = 0.12, Z = 4.84, $p < .001$, 95 % CI [0.36, 0.85]). Heterogeneity was extremely high ($I^2 = 94.92$ %, $\tau^2 = 0.18$, Q(12) = 236.07, $p < .001$), suggesting substantial variability in effects across studies. The forest plot is displayed in Fig. 5. The third random-effects meta-analysis, based on eight pre-post psychological distress outcomes, identified a small but statistically significant pooled effect ($g = 0.28$, SE = 0.12, Z = 2.28, $p = .023$, 95 % CI [0.04, 0.52]). Heterogeneity was substantial ($I^2 = 81.57$ %, $\tau^2 = 0.09$, Q(7) = 37.97, $p < .001$), indicating notable variability in effect sizes across studies. The forest plot is presented in Fig. 6.

3.5.2. SWiM analysis

Four studies were included in the SWiM synthesis due to insufficient data for meta-analysis (Arbuthnott & Sutter, 2019; Tracey et al., 2018), single-item indicators rather than full scale measures (Hignett et al., 2018), and small group numbers ($n = 8$; Lown et al., 2023). Arbuthnott and Sutter (2019) reported that adolescents in the nature-based song writing programme showed significantly lower negative affect than classroom participants (F(1,34) = 8.20, p = .007, $\eta^2 = 0.19$), although missing means and SDs prevented effect-size calculation. Hignett et al. (2018) evaluated a 12-week surfing programme for adolescents

Table 2
Summary of included studies.

Author (Year)	Country	Participants			Intervention Type	Outcome Measure	Assessment Timepoint Analysed	Ethical Conduct	Main Findings
		n Enrolled/ Analysed	Age *M* (SD)	% female					
Albedry et al. (2023)	USA	95/65	*15.0* (0.6)	52.6	Adventure (challenging)	CD-RISC-10	T1:Baseline T2: Post intervention	University Michigan IRB (HUM00208514)	Significant improvements in resilience after semester-long adventure education curriculum.
Allan et al. (2025)	UK	622/622	*16.5**	58.0	Outdoor adventure education (residential camp)	CD-RISC-10	T1: Arrival T2: End of week	Sheffield Hallam University Ethics	Increased resilience (36 %) and well-being (23 %) after camp-based experiences.
Arbuthnott and Sutter (2019)	Canada	I: 15/15 C: 23/23	*14.5**	NR	Nature-based music/adventure camp	PANAS-C/ DASS	T1: Pre arrival/start T2: End of trip	University of Regina Ethics	Significant improvement in elevating emotions for those in natural settings.
Barton et al. (2016)	UK/SA	130/117	*14.5**	57.0	Wilderness expedition	RSES	T1: Pre-expedition T2: post-expedition	University of Essex Ethics	Significant increases in self-esteem and nature-connectedness.
Bowen et al. (2016)	Australia	36/36	*14.6* (1.6)	58.3	Wilderness Adventure Therapy (WAT)	RQ/BDI-II	T1: Pre-program T2: Post-program	Conducted through Barwon Health	Moderate, statistically significant improvements in psychological resilience and social self-esteem.
Bowen & Neill (2016)	Australia	36/36	*14.0* (0.7*)*	30.0	Catalyst outdoor adventure program	GWB - PD	T1: Pre trip T2: Post trip	University of Canberra HREC	Small-moderate worsening of psychological distress very small improvement in well-being.
Choe et al. (2025)	Hong Kong	I: 33/32 C: 45/45	*14.4**	47.0	Nature-based outdoor activities (1-day & 4-day)	SCS-R	T1: Baseline T2: Post-program	PolyU IRB	Small significant increase in social connectedness for four-day group.
Dong et al. (2025)	China	I:16/16 C:15/15	*12.1* (0.3)	53.2	Mindfulness-based intervention in different environments	PANAS-C	T1: Baseline T2: 6 weeks Post	Suzhou University Ethics	Outdoor mindfulness led to significant improvement in self-efficacy, positive affect, and reduction in negative affect.
Gabrielsen et al. (2019b)	Norway	32/32	*16.5* (0.6)	65.6	Friluftsterapi (wilderness therapy)	SWLS/ HADS-A	T1: Baseline T2: Post-treatment	REK 2013/1841)	Moderate significant improvement in self-efficacy.
Gabrielsen et al. (2019a)	Norway	33/32	*17.0**	70.0	Friluftsterapi (wilderness therapy – anxiety pilot)	STAI-S	T1: Start of program T2: Final day	REK 2013/1841 & 2016/2228	Significant reduction in anxiety between the first and final days.
Hignett et al. (2018)	UK	58/36	*14.2**	17.0	Surf to Success (surfing + environmental education)	PBHS-Y	T1:1 week pre T2:1 week post	Plymouth University Ethics	Small significant increase in social connectedness to friends.
Keller et al. (2023)	USA	24/16	*17.0**	NR	Forest bathing	WEMWBS	T1: Baseline T3: Post final session	Antioch University IRB	Moderate/large significant increase in well-being significantly after forest bathing.
Koni et al. (2019) Study A	NZ	136/133	*16.6* (1.7)	60.3	Sail-training voyage	RS-15	T1: Start of voyage T2: End of voyage	Otago Ethics	Moderate statistically significant increase resilience post 10 days sailing.
Koni et al. (2019) Study B	NZ	91/88	*15.3* (1.2)	60.4	Sail-training voyage with Māori focus	RS-15	T1: Start of voyage T2: End of voyage	Otago Ethics	Moderate statistically significant increase in resilience post 7 days sailing.
Lown et al. (2023)	UK	8/8	*15.5**	50	SYATS wilderness therapy	PROMIS	T1: Before program T2: End Program	IRB Legacy Health (Portland OR)	Improved psychosocial outcomes in anxiety, depression, fatigue, and peer relations.
McAnally et al. (2018)	NZ	I: 51/51 C: 53/44	I: *14.5** C: *14.4*	0.0	Tihoi residential outdoor education	RSES	T1: Baseline T2: F-up – Week 15	Otago Ethics	Small significant improvements in life satisfaction, self-esteem, and gratitude.
McEwan et al. (2022)	UK	39/34	*13.1* (1.7)	44	ParkBathe urban forest-bathing	POMS	T1: Before session T2: Post session	University of Derby Ethics	Significant improvements in anxiety, rumination, scepticism, and social connection.
Mutz & Müller (2016)	Germany Norway	12/12	*14.0**	42	Alpine crossing outdoor adventure	GSES/PSQ	T1: 1 wk pre-program T2: 4 days post-program	Institutional ethics NR	Significant increase in life satisfaction, mindfulness, non-significant change in self-efficacy or worries.
Rose et al. (2018)	Australia	160/150	*15.0* (0.5)	62	Journey-based outdoor youth program	GSES/ EATQ-R-D	T2: 2 wk pre journey	Not reported	Improvement in emotional well-being, fear and self-

(*continued on next page*)

Table 2 (*continued*)

Author (Year)	Country	Participants			Intervention Type	Outcome Measure	Assessment Timepoint Analysed	Ethical Conduct	Main Findings
		n Enrolled/ Analysed	Age *M* (SD)	% female					
							T3: 1 wk post journey		efficacy, and school connectedness.
Scarf et al. (2016)	NZ	60	*16.5**	53.3	Spirit of Adventure AEP	RS-15	T2: Day 1 of voyage T3: Day 10 end	Not reported	Group belonging makes a significant contribution to the improvement in resilience.
Scarf et al. (2017)	NZ	1: 90/90 C: 90/90	I: *16.7* C: *16.4*	56.7	Spirit of Adventure AEP (resilience study)	RS-15	T1: Day 1 of voyage T2: Day 10 end voyage	Otago Ethics	Voyage participants reported significantly higher levels of resilience than control.
Scarf et al. (2018)	NZ	I: 100/97 C: 91/73	*16.5**	I: 48.0 C: 72.6	Spirit of Adventure AEP (self-esteem/ needs)	Self Esteem LES	T1: Day 1 of voyage T2: Day 10 end voyage	Otago Ethics	Sense of belonging to Watch Group predicted increases in self-esteem following.
Scarf et al. (2018)	NZ	I: 80/80 C: 91/91	*16.5**	I: 48.0 C: 72.6	Spirit of Adventure AEP (self-esteem/ needs)	SDQ-III	T1: Day 1 of voyage T2: Day 10 end voyage	Otago Ethics	Sense of belonging to Watch Group predicted increases in self-esteem following.
Sprague and Ekenga (2022)	USA	I: 297/ 297 C: 65/65	I:*11.4* (1.2) C:*12.7* (0.6)	47.8	Nature-based education (NBE)	HRQoL	T1: Pre-interv T2: Post-intervention	Washington Univ IRB	Significant improvements in intervention HRQoL domain scores. Decline in control group.
Tracey et al. (2018)	Australia	9/9	*11.7**	11.1	ACT in the Outdoors (ACT + adventure)	KESSLER10	T1: Pre - Baseline T2: Post - 8 weeks	Western Sydney Univ + NSW Dept	Two participants experienced significant reductions in anxiety and depression.
Whittington and Aspelmeier (2018)	USA	711/708	*12.0**	100.0	Girls' camps (AE, EE, traditional, mixed)	AGRS	T1: Pre - first day T2: Post - last day	IRB approval	Small significant increase in resilience across 4 program types.
Zeng et al. (2025)	China	129/129	*14.5* (0.7)	31.0	Nature-based mind–body intervention	SCARED	T1: 1 week prior T2: Post-test	Chinese Academy of Sciences IRB	Significant decrease in anxiety and depressive symptoms for those with pre-existing symptoms.

Note: * No SD reported; IRB (Internal Review Board); AGRS (Adolescent Girls' Resilience Scale); BDI-II (Beck Depression Inventory-II); CD-RISC-10 (Connor–Davidson Resilience Scale – 10-item); EATQ-R-D (Early Adolescent Temperament Questionnaire – Revised – Depression Subscale); GSES (General Self-Efficacy Scale); GWB (General Well-Being); HADS-A (Anxiety) HRQoL-E(Health-Related Quality of Life-Emotional); Inclusion/Belong (Sheldon & Bettencourt Inclusion/Belonging Scale); PANAS (Positive and Negative Affect Schedule for Children); PBHS-Y (Positive Behaviour and Health Scale – Youth); POMS-Tension (Profile of Mood States – Tension); PSQ-Worry (Perceived Stress Questionnaire – Worry Index); RS-15 (Resilience Scale – 15 items); RSES (Rosenberg Self-Esteem Scale); SCARED (Screen for Child Anxiety Related Emotional Disorders); SCS-R (Social Connectedness Scale – Revised); STAI-S (State-Trait Anxiety Inventory – State); WEMWBS (Warwick–Edinburgh Mental Well-Being Scale.

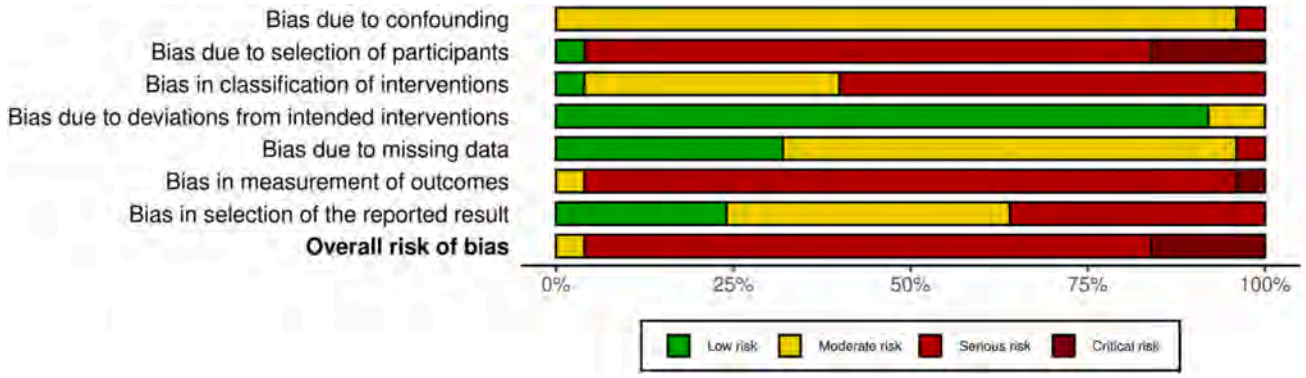

Fig. 2. ROBINS-I summary plot.

excluded or at risk of exclusion from school and observed improvements in appearance satisfaction, school connectedness, resting heart rate, and teacher-rated social skills and motivation; however, outcomes were measured using single BPHS-Y items and mental-health data were not fully reported. Lown et al. (2023) found small-to-moderate gains in physical functioning, fatigue, anxiety, and peer relations following a nine-day wilderness programme for adolescents undergoing or recently completing cancer treatment, supported by qualitative reports of accomplishment, bonding, and connection with nature. Finally, Tracey et al. (2018) presented individual reliable-change data from an eight-week ACT-in-the-outdoors intervention, with two adolescents demonstrating reliable reductions in distress. Across all four studies, the

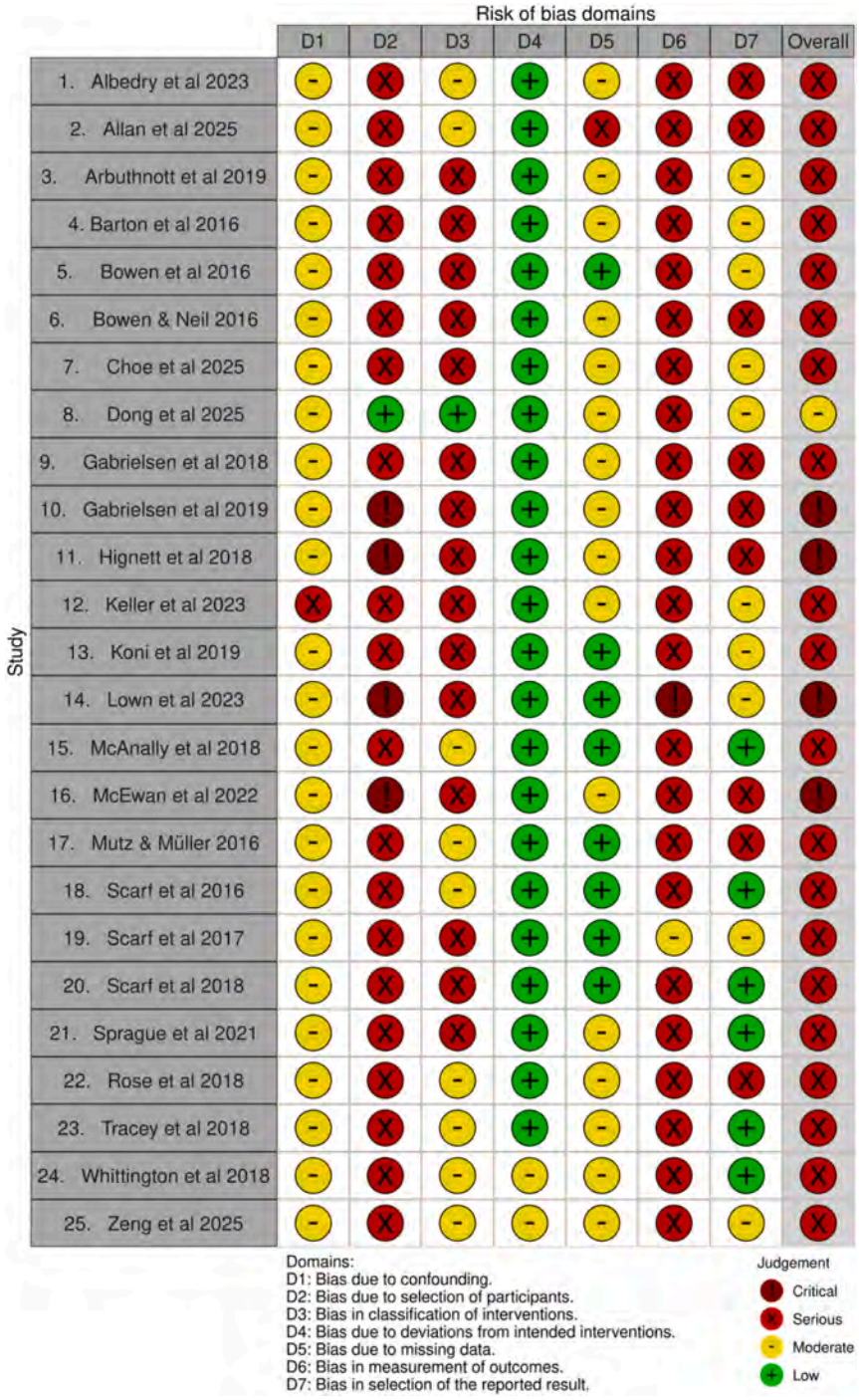

Fig. 3. ROBINS-I traffic light plot.

certainty of evidence was very low due to uncontrolled designs, incomplete reporting, and small samples. Collectively, these findings offer suggestive but non-definitive evidence that NBIs may benefit specific adolescent subgroups.

3.5.3. Subgroup and sensitivity analysis

Subgroup analyses were planned; however, consistent with the protocol requirement of at least three studies per subgroup, meaningful subgroup meta-analysis was not possible due to an insufficient number of studies per category. Exploratory splits (e.g., adventure-based vs. ecotherapy programs; wilderness vs. school-based programs) did not materially reduce heterogeneity in any meta-analytic model (all $I^2 > 80$ %), indicating that differences in program type could not explain the substantial variability in effect sizes. Sensitivity analyses excluding studies with small samples (<30 participants) also produced no meaningful change to the direction, statistical significance, or magnitude of pooled effects, confirming that results were not driven by small-sample studies.

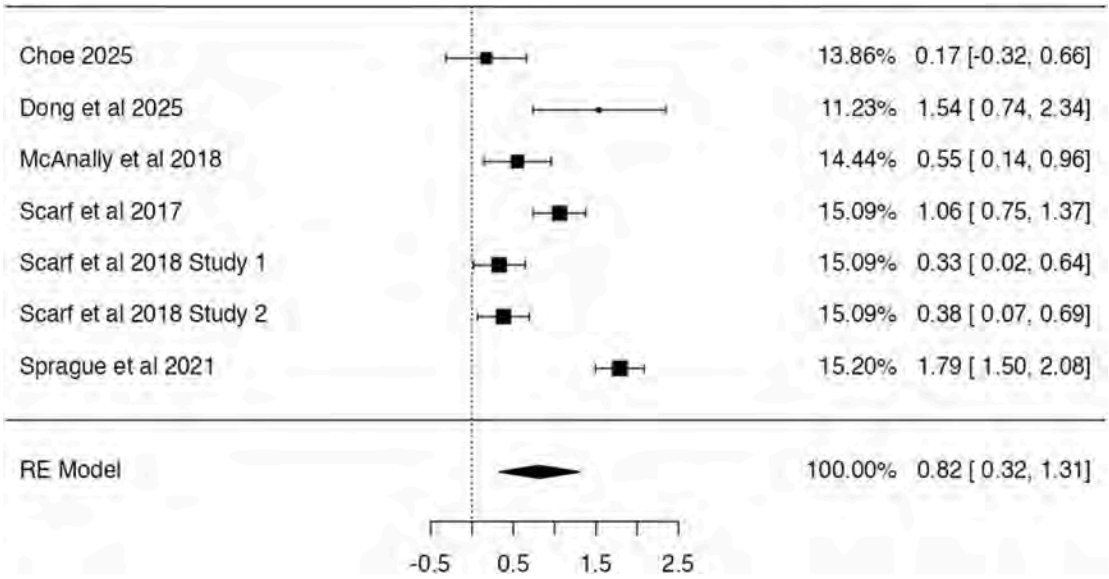

Fig. 4. Forest plot for mental health between-group changes of non-randomised controlled trials.

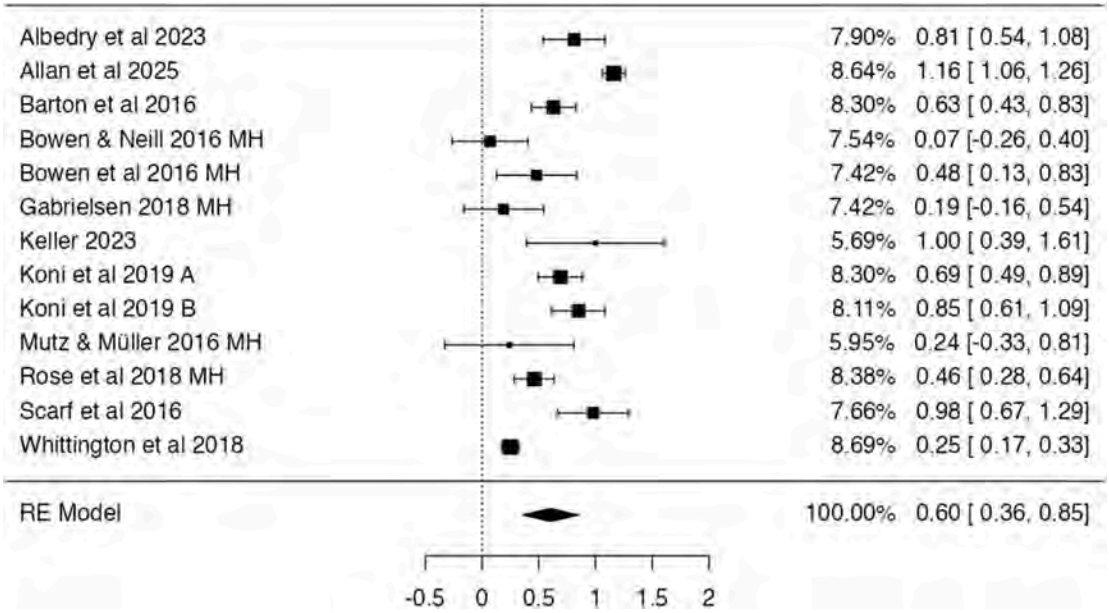

Fig. 5. Forest plot for mental health within-group pre–post changes single-group studies.
Note. MH = Mental Health.

3.5.4. Effectiveness of key components and characteristics of group-based NBIs

Descriptive synthesis indicated that group-based NBIs were broadly associated with improvements in mental health and psychological distress; however, the magnitude of benefit varied according to program structure and delivery. Patterns of effectiveness across studies are summarised in Table 3. The categories in Table 3 were developed through an iterative coding process during data extraction. After identifying core program characteristics (setting, duration, facilitation, and contents), studies were grouped according to patterns in effectiveness rather than by program name (e.g., "wilderness therapy"). This approach enabled common active ingredients to be identified across differently named models. The resulting categories therefore represent clusters of program features that tended to co-occur in studies showing similar levels of mental-health improvement. These groupings emerged inductively from the evidence offering a practical lens for understanding which combinations of characteristics appear most influential for adolescent mental health.

Across interventions, larger effects were most consistently observed in programs involving multi-day or residential immersion, high physical and emotional challenge, shared living and responsibility, and structured group reflection. In contrast, brief or low-dose park-based ecotherapy programs tended to generate small effects. Facilitator expertise also aligned with outcome magnitude, with the most favourable results emerging when programs were delivered by specialist clinicians or highly trained outdoor educators rather than general school staff or

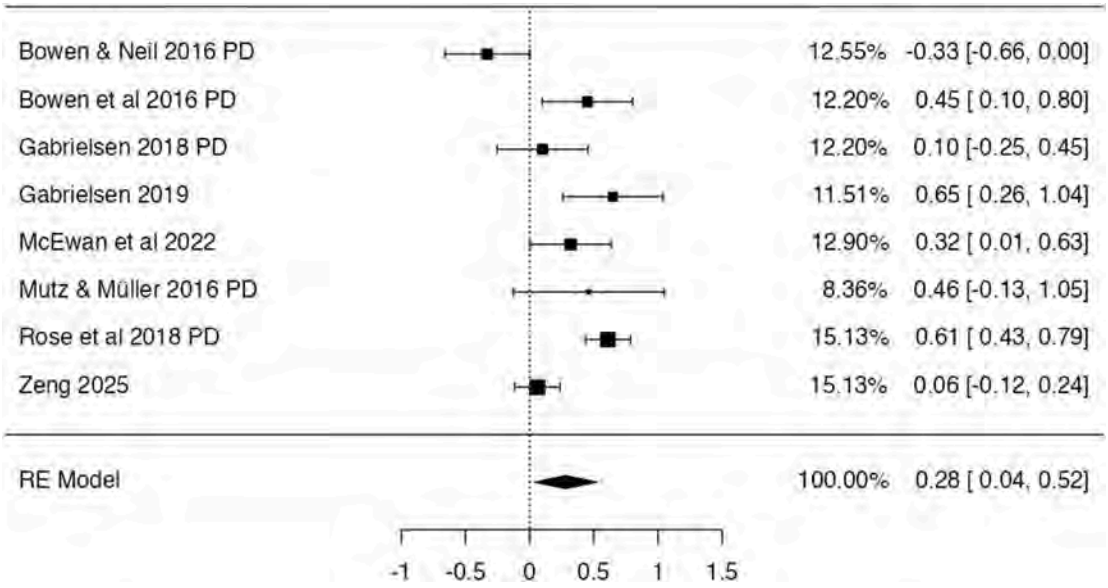

Fig. 6. Forest plot for psychological distress within-group pre–post changes single-group studies.
Note. PD = Psychological Distress.

volunteers.

Outcomes related to resilience, self-esteem, social connectedness, and wellbeing were most responsive to NBIs, whereas reductions in anxiety, depression, and stress were comparatively modest unless therapeutic elements were deeply integrated across sessions rather than delivered as supplementary activities. These patterns should be interpreted cautiously, as they arise from between-study comparisons rather than formal subgroup meta-analysis.

3.6. Assessment of publication bias

Publication bias was assessed separately for each of the three meta-analytic models, in line with PRISMA 2020 and APA JARS-Meta-Analysis guidelines, using both visual and inferential methods. Analyses were conducted in Jamovi (v. 2.3) using the MAJOR module. For each model, funnel plots were inspected for symmetry, and Egger's regression, Kendall's Tau, and Rosenthal's Fail-Safe N were used to evaluate small-study effects ($\alpha = .05$). Given the substantial heterogeneity across models, results were interpreted cautiously.

For the quasi-experimental meta-analysis, neither Egger's regression nor Kendall's Tau indicated small-study effects (Egger $p = .660$; Kendall's Tau $p = 1.000$), and the Fail-Safe N was large ($N = 327$), suggesting the pooled effect is unlikely to be overturned by unpublished null findings. Funnel-plot asymmetry was mild and not consistent with systematic publication bias. For the pre-post mental-health meta-analysis, publication-bias tests again showed no evidence of small-study effects (Egger $p = .759$; Kendall's Tau $p = 1.000$), and the Fail-Safe N was extremely large ($N = 2063$), indicating strong robustness of the pooled effect. Wide dispersion in the funnel plot appeared attributable to heterogeneity rather than directional bias. For the pre-post psychological-distress meta-analysis, some vulnerability to publication bias was apparent. Although Kendall's Tau was non-significant ($p = .615$), the Fail-Safe N was small ($N = 79$), and funnel-plot asymmetry suggested possible small-study or selective-reporting effects.

3.7. Certainty of evidence

The certainty of evidence was evaluated using the GRADE framework (GRADE Working Group, 2004). Evidence from the quasi-experimental meta-analysis started at low certainty (non-randomised design) and was downgraded for serious risk of bias and very high heterogeneity ($I^2 = 91.72$ %). Although the large pooled effect size ($g = 0.82$) met criteria for upgrading, this did not offset the multiple downgrading factors, resulting in an overall low certainty of evidence. Evidence from the pre-post mental-health meta-analysis started at very low certainty (uncontrolled design) and was further downgraded for extremely high heterogeneity ($I^2 = 94.92$ %), resulting in very low certainty of evidence.

Evidence from the pre-post psychological-distress meta-analysis also remained at very low certainty, reflecting uncontrolled designs, substantial heterogeneity ($I^2 = 81.57$ %), and signs of vulnerability to publication bias. Although formal publication-bias tests were non-significant for the first two models, caution is warranted due to the predominance of positive findings and variability in methodological quality across the field. A complete GRADE Summary of Findings is in Appendix E (Table E1), and publication-bias funnel plots are provided in Appendix F, Figures F1, F2 and F3.

4. Discussion

4.1. Summary of main findings

This systematic review and meta-analysis synthesised 25 peer-reviewed studies of group-based NBIs delivered to adolescents aged 11–19 across nine countries (2015–2025). Across diverse formats, including adventure education, wilderness expeditions, sailing, surfing, environmental education, forest bathing, mindfulness, and ACT-informed outdoor therapy, all programs involved structured engagement with real, physical natural environments in a group setting. Results indicated that NBIs were consistently associated with improvements in adolescent mental health.

Three meta-analyses were conducted to examine outcomes across study designs. Quasi-experimental studies showed a large pooled effect on mental health ($g = 0.82$), pre-post studies showed a moderate improvement in mental health ($g = 0.60$), and pre-post studies measuring distress outcomes showed a small but statistically significant reduction in psychological distress ($g = 0.28$). Four additional studies synthesised narratively (SWiM) showed selective improvements in emotional wellbeing or distress for some participants; however, conclusions were limited due to very small samples, incomplete reporting,

Table 3
Characteristics and observed patterns of effectiveness of NBIs.

Category	Characteristics/ Observed Patterns	Example Programs/Studies	Associated Effect Sizes
Highest-effect NBI structures	Multi-day or residential format; high physical and emotional challenge; shared responsibility; novelty; cohort living; structured reflection; group identity emphasis	Sprague and Ekenga, 2022; Dong et al., 2025; Allan et al., 2025; Keller et al., 2023; Scarf et al., 2017	Large to very large ($g \geq 1.00$)
Moderately effective structures	Adventure-based challenges; camping or expeditions; teamwork and leadership; journaling or reflective activities; strong but shorter immersion	Koni et al., 2019; Albedry et al., 2023; Gabrielsen et al., 2019a; Barton et al., 2016; Rose et al., 2018	Moderate ($g = 0.40–0.85$)
Lower-effect structures	Brief/no overnight stay; light sensory/ mindfulness tasks; urban-park delivery; minimal challenge; limited reflection	McEwan et al., 2022; Choe et al., 2025; Whittington and Aspelmeier, 2018; Zeng et al., 2025	Small ($g = 0.05–0.32$)
Facilitator characteristics associated with higher effects	Trained clinical staff, certified mindfulness/forest-bathing instructors, or highly specialised outdoor educators	Dong et al., 2025; Keller et al., 2023; Sprague and Ekenga, 2022; Scarf 2016–2018; Allan et al., 2025	Large effects
Facilitator characteristics associated with moderate effects	Outdoor educators and youth-development leaders integrating reflection and teamwork into challenges	Koni et al., 2019; Barton et al., 2016; Rose et al., 2018; Albedry et al., 2023	Moderate effects
Facilitator characteristics associated with lower effects	School staff or volunteers delivering nature-based activities without high immersion or intensive facilitation	McEwan et al., 2022; Whittington and Aspelmeier, 2018; Zeng et al., 2025	Small effects
Most responsive outcomes	Resilience, self-esteem, wellbeing, social connectedness, belonging, self-efficacy	Allan et al., 2025; Dong et al., 2025; Keller et al., 2023; Koni et al., 2019; Scarf et al. 2016–2018	Moderate to large improvement
Least responsive outcomes	Anxiety, depression, stress	Bowen & Neill PD (2016); Gabrielsen et al. PD (2019b); McEwan et al., 2022; Zeng et al., 2025	Small or non-significant
Mechanisms appearing to drive strongest effects	Group belonging, shared challenge, mastery of new skills, identity development, peer feedback	Allan et al., 2025; Scarf 2016–2018; Koni et al., 2019; Sprague and Ekenga, 2022	–
Dose-response patterns	Higher duration and immersion reported larger effect	Multi-day > multi-session > single-session	–
Therapeutic intentionality	Clinical content (e.g., MBSR, ACT) improved outcomes when embedded across sessions	Dong et al., 2025; Keller et al., 2023; Tracey et al., 2018 (SWiM)	Large effects when CC integrated

and absence of control groups.

Although effect sizes varied widely, descriptive patterns indicated that the largest short-term improvements occurred in high-immersion programs such as multi-day wilderness expeditions and multi-week therapeutic or mindfulness programs, whereas brief and low-dose eco-therapy sessions produced comparatively smaller gains. Effects were also larger when programs were delivered by specialist or clinically trained facilitators (e.g., mindfulness practitioners, forest-bathing guides, wilderness therapists, mental-health clinicians), while school staff or volunteer-led delivery was typically associated with smaller changes. These observations are correlational rather than causal but may help to account for the substantial heterogeneity observed across studies.

4.1.1. Alignment to theoretical models

The pattern of effects across outcome domains aligns with theoretical mechanisms proposed in that NBIs produced larger improvements in promotive mental-health constructs (e.g., resilience, self-esteem, social connectedness, belonging, and wellbeing) than in reductions in anxiety, depression, and stress. This is consistent with the Biophilia Hypothesis (Wilson, 1984), ART (Kaplan, 1995), and Stress Reduction Theory (Ulrich, 1983), which posit that natural environments restore attentional capacity, elicit positive affect, and promote calm.

Refinements of ART emphasise soft fascination, gently engaging stimuli such as rustling leaves or patterns of light, which allow cognitive space for reflection and emotional processing (Basu et al., 2019; Kaplan, 1995). In contrast to the hard-fascination, attention-filling stimulation characteristic of screen use, soft-fascinating natural environments preserve mental bandwidth for reflection and may counterbalance the cognitive load associated with adolescents' high digital engagement. Because soft fascination involves attending to stimuli that require very little cognitive effort while preserving mental bandwidth for reflection, it is possible that it may support self-regulation and the strengthening of internal psychological resources, rather than directly targeting clinical symptoms of anxiety or depression. This mechanism aligns with the pattern observed in this review: promotive mental-health outcomes (e.g., resilience, self-esteem, belonging, and wellbeing) showed the largest improvements, whereas reductions in psychological-distress symptoms were smaller.

The dose-response pattern in Table C1 further reinforces this mechanism. Programs with the highest effect sizes ($g \geq 1.00$) consistently involved extended exposure to natural environments, where soft-fascinating sensory cues were continuously available (e.g., multi-day wilderness expeditions, tall-ship voyages, and multi-week mindfulness in nature). In contrast, brief park-based sessions, and low-dose sensory-mindfulness activities, where exposure to soft-fascinating cues was short and easily interrupted, produced small effects.

These results suggest that NBIs may be most effective when they combine sustained exposure to soft-fascinating natural environments with group-based challenge and belonging, enabling adolescents to experience competence, autonomy, affiliation, and identity development. This constellation of mechanisms aligns with the large effects observed for promotive mental-health outcomes and the smaller effects for psychological distress symptoms reflected across the three meta-analyses.

4.2. Interpretation in the context of existing evidence

This review builds upon the existing evidence base on NBIs. Previous meta-analyses in adult samples have demonstrated broad mental-health benefits of nature-based therapies, (Coventry et al., 2021), yet did not examine whether outcomes differed according to program characteristics. Adolescent-focused reviews similarly report improvements in self-esteem, stress, and resilience (Overbey et al., 2023; Roberts et al., 2019; Tillmann et al., 2018), but lacked analysis of the specific contribution of group processes, despite adolescence being a developmental

period in which peer connection and collective identity strongly shape wellbeing. By focusing exclusively on group-based NBIs, the present review provides targeted evidence for adolescents.

4.3. Strengths and limitations of the evidence base

The ecological realism of the interventions represents a notable strength. All programs were delivered in real-world natural environments, defined as genuine outdoor settings with natural features (e.g., forests, beaches, parks) rather than simulated or indoor spaces, suggesting that group-based NBIs could be implemented across a wide range of educational and community contexts. At the same time, several important limitations reduce the certainty of the evidence. No randomised controlled trials were identified, and ROBINS-I ratings indicated moderate to serious risk of bias across most studies. Common issues included confounding, self-selection into programs, non-equivalent comparison groups, and reliance on unblinded self-report measures. Substantial heterogeneity across intervention formats, duration, intensity, and outcome measures contributed to high I^2 values and limited the ability to isolate specific effective components.

Although publication-bias tests were largely reassuring the psychological-distress model showed signs of small-study or selective-reporting effects, and the predominance of positive findings means publication bias cannot be ruled out. In addition, qualitative-only studies and those focusing exclusively on physiological outcomes were excluded, which restricts insight into mechanisms, acceptability, and lived experience. When combined, these limitations explain the low-to-very-low certainty ratings in the GRADE assessment and indicate that, while the direction of effects is encouraging, conclusions should be interpreted with appropriate caution.

4.4. Strengths and limitations of the review

Methodological strengths of this review include adhering to PRISMA and PRISMA-P guidelines, prospectively registering on PROSPERO, and being accepted as a Stage 1 Registered Report. A comprehensive, librarian-assisted search strategy was used across multiple databases, with clearly defined PICOS criteria and an operational definition of group-based NBIs to ensure conceptual clarity. Study screening, data extraction, and risk-of-bias assessments were conducted using Covidence with structured templates, and risk-of-bias was evaluated using ROBINS-I, with certainty of evidence appraised using GRADE. Quantitative synthesis followed Cochrane-recommended procedures, including random-effects modelling, separate analyses by study design, and SWiM methods for studies unsuitable for meta-analysis.

Nonetheless, several limitations of the review should be acknowledged, including restricting inclusion to peer-reviewed journal articles, which may have excluded relevant grey literature (e.g., school or community evaluations), potentially amplifying publication bias. Additionally, although the search strategy covered a wide range of wellbeing, mental health, and psychosocial outcomes, it did not explicitly include emotion- or mood-related terms, such as positive or negative affect, which may have led to an underrepresentation of studies that primarily frame outcomes in affective terms. Data extraction was led by a single primary reviewer with secondary checking rather than full dual extraction, introducing a minor risk of extraction error despite consensus procedures. Planned subgroup and sensitivity analyses were constrained by the small number of studies per subgroup, limiting the ability to examine moderators or active components. Finally, necessary decisions, such as excluding qualitative-only studies and physiological-only outcome studies, may have reduced the breadth of contextual insight regarding mechanisms, acceptability, and implementation.

4.5. Implications for practice and policy

The findings suggest that NBIs show promise as promotive and preventive mental-health supports for adolescents rather than primary treatments for acute clinical distress. Programs may be particularly appropriate in school and youth-development contexts where the goal is to enhance resilience, self-esteem, belonging, and wellbeing.

NBI design features associated with the largest improvements include extended immersion in nature, shared challenge, structured group reflection, and delivery by specialist facilitators (e.g., clinical or therapeutic staff, certified mindfulness/forest-bathing practitioners, or experienced outdoor educators). School or volunteer-led sensory or ecotherapy programs may still be valuable but appear to produce comparatively smaller gains unless delivered at sufficient duration and depth.

Given the global increase in screen time and its association with psychological distress, NBIs may offer a useful counterbalance by providing opportunities for soft-fascination-based attentional restoration, embodied activity, and in-person social connection, experiences that are increasingly scarce in highly digital daily life.

4.6. Implications for future research and conclusion

Future research would benefit from high-quality randomised controlled trials, including cluster-RCTs in school settings, to improve certainty of evidence and reduce bias. Quasi-experimental field studies remain valuable for evaluating ecologically embedded programs that cannot feasibly be randomised but should incorporate stronger comparators, preregistration, and blinding of outcome assessment where possible. Measurement priorities include consistent use of validated tools, repeated measurement over time, and inclusion of both promotive mental-health and distress outcomes to clarify whether mechanisms differ by outcome domain. Mixed-methods approaches are recommended to integrate quantitative change with qualitative insight into mechanisms, acceptability, and adolescent lived experience. Future research could more explicitly incorporate blue-space NBI terminology such as coastal, surfing, or sailing programs, which may be underrepresented in the current evidence base due to the predominance of green-space terminology in search strategies. Finally, mechanism-focused research, including the roles of soft fascination, group belonging, identity development, and emotion-regulation scaffolding, may clarify how NBIs exert their effects and help optimise program design.

In conclusion, this systematic review and meta-analysis provides, to the authors' knowledge, the most up-to-date comprehensive synthesis of group-based nature-based interventions for adolescent mental health. Across 25 studies, NBIs were associated with moderate to large improvements in mental health outcomes, particularly resilience, self-esteem, and small reductions in distress. However, the overall certainty of evidence was low to very low due to non-randomised designs, risk of bias, and high heterogeneity. NBIs should therefore be viewed as promising but not yet definitively established approaches. Continued investment in rigorous, theory-driven, and equity-focused research will be essential to determine how best to harness nature-based group programs to support adolescent mental health at scale.

CRediT authorship contribution statement

Robyn Campbell: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Violette McGaw:** Writing – review & editing, Supervision. **Andrea Reupert:** Writing – review & editing, Supervision.

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Declaration of conflicting interests

The author(s) declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Appendix A

Table A1
Search Terms

	Search No.	Search terms
Search for population (Adolescents)	1.	Adolescen*
	2.	Youth*
	3.	"Young person"
	4.	Child*
	5.	Student*
	6.	Teen*
	7.	OR/1-6
Search for intervention (Nature-based)	8.	Natur* therap*
	9.	Natur*
	10.	Nature-based therap*
	11.	Nature-based intervention*
	12.	Outdoor adj3 therap*
	13.	Walk-and-talk therap*
	14.	"Wilderness therap*"
	15.	"Adventure therap*"
	16.	Ecotherap*
	17.	Exposure adj2 nature
	18.	Shinrin-yoku
	19.	"Forest bath*"
	20.	"Bush therap*"
	21.	"Woodland therap*"
	22.	OR/8-21
Search for outcome (Psychological Distress or Mental Health)	23.	Restorat*
	24.	Distress
	25.	Stress*
	26.	Anxiety
	27.	Depressi*
	28.	Psychological*
	29.	Wellbeing
	30.	Well-being
	31.	"Psychological health"
	32.	"Mental health"
	33.	Mood
	34.	OR/23-33
Combine population, intervention, outcome	35.	7 AND 22 AND 34

Appendix B

Search syntax and filters for APA PsycINFO (OVID)

Search strategy for identifying relevant studies:

((Adolescen* or Teen* or Youth* or "Young person" or Child* or Student*)). mp. AND ((“Natur* therap*” or “Natur*” or “Nature-based therap*” or “Nature-based intervention*” or “Outdoor adj3 therap*” or “Walk and talk therap*” or “Wilderness therap*” or “Adventure therap*” or Ecotherap* or “Exposure adj2 nature” or “Shinrin yoku” or “Forest bath*” or “Woodland therap*” or “Bush therap*”)). m_titl. AND ((Restorat* or Distress or Stress* or Anxiety or Depressi* or Psychological* or wellbeing or well-being or “Psychological health” or “Mental health” or Mood)). m_titl.

Filters applied

Filters include study types such as clinical trials, empirical and experimental studies, follow-up, longitudinal, prospective, and retrospective studies, as well as quantitative and treatment outcome studies. Results are limited to peer-reviewed journal articles published between 2015 and the present.

Appendix C

Table C1
Standardised Mean Differences (Hedges' g), Standard Errors (SE) for Meta-Analytic Studies

Author (Year)	Domain/Outcome Measure	Scale range/scoring direction	g	se	n	Measure/Arm Reasoning	Study Design Time: Mean: SD:
Albedry et al. (2023)	Resilience CD-RISC-10	0–50; higher = greater resilience	0.81	0.14	65	Resilience is only relevant outcome	Pre-Post Within group T1: M: 4.15 SD 0.49 T2: M: 3.69 SD 0.62
Allan et al. (2025)	Resilience CD-RISC-10	0–50; higher = greater resilience	1.16	0.05	622	Resilience and wellbeing. Used resilience as wellbeing non-validated	Pre-Post Within group T1: 20.64 SD 5.71 T2: 28.14 SD 7.16
Arbuthnott and Sutter (2019)	PANAS-C/DASS-21	1–5; higher = greater positive emotion	–	–	38	Insufficient data for meta-analysis	SWiM report only
Barton et al. (2016)	Self-Esteem RSES	10–40; higher = better self-esteem	0.63	0.10	117	Self-esteem was only relevant outcome	Pre-Post within group T1: M: 30.0 SD 4.2 T2: M: 32.7 SD 4.3
Bowen & Neill 2016 MH	Wellbeing GWB	5-40 Higher = better well-being	0.07	0.17	36	GWB used as is only relevant outcome	Pre-Post within group T1: M: 5.47 SD 1.71 T2: M: 5.60 SD 1.73
Bowen & Neill 2016 PD	Distress GWB	5-40 Lower = less distress	−0.33	0.17	36	GWB used as is only relevant outcome	Pre-Post within group T1: M: 5.38 SD 1.82 T2: M: 4.82 SD: 1.5
Bowen et al., 2016 PD	Depression BDI-II	0–63; higher = more depression	0.45	0.18	36	Resilience, depression, self-esteem, family functioning. Depression due to only relevant psychological distress measure	Pre-Post within group T1: M 42.33 SD 15.26 T2: M: 48.63 SD 12.04
Bowen et al., 2016 MH	Resilience Questionnaire (RQ)	14–78; higher = greater resilience	0.48	0.18	36	Resilience, depression, self-esteem, family functioning. Resilience due self-esteem inc. family functioning etc.	Pre-Post within group T1: M: 33.53 SD 12.09 T2: M: 38.94 SD 9.80
Choe et al. (2025)	Social Connectedness SCS-R	20–120; higher = greater connectedness	0.170	0.25	I: 32 C: 45	Social connectedness - only relevant outcome 4-day arm - full dose group	Between group NBI T2 M:73.97 SD:10.78 Control T2 M:72.49 SD:5.37
Dong et al. (2025)	Positive Affect PANAS-C	1–5; higher = greater positive emotion	1.54	0.41	I:16 C:15	Positive as not enough neg outcomes for subgroup analysis. Outdoor arm – only relevant	Between group Outdoor T2:3.86 SD:0.33 Control T2 M: 3.36 SD:0.30
Gabrielsen et al. MH (2019a)	Life satisfaction/ Wellbeing SWLS	5 items; higher score = more life satisfaction	0.19	0.18	32	SWLS – validated & most widely used scale. SOC, GSE, FFMQ -positive psychology/coping. SHR is single item. LEQ life effectiveness	Pre-Post within group T1: M: 24.5 SD 6.4 T2: M: 25.9 SD 7.6
Gabrielsen et al. PD (2019a)	HADS Anxiety	7 items; lower score = less anxiety	0.10	0.18	32	HADS Anxiety & Depression, YOQ. YOQ too broad and anxiety due to most common measured across studies.	Pre-Post within group T1: M: 11.6 SD: 4.9 T2: M: 11.1 SD: 5.0
Gabrielsen et al. (2019b)	Anxiety STAI-S	20–80; higher = more anxiety	0.65	0.20	31	Anxiety only relevant validated measure.	Pre-Post within group T1: M: 45.1 SD 14.1 M: 38.2 SD 13.5
Hignett et al. (2018)	BPHS-Y	1-7; higher = better well-being	–	–	35	Single domains only for BPHS-Y. Only one item per domain.	SWiM report only
Keller et al. (2023)	Wellbeing WEMWBS	14–70; higher = better well-being	1.00	0.31	16	WEMWBS only relevant measure. Three session arm	Pre-Post within group T1: M:47.8 SD: 3.2 T3 M:56.3, SD: 4.0
Koni et al., 2019 A	Resilience Wagnild & Young R-15	25–125; higher = greater resilience	0.69	0.10	133	Resilience and social identity measures. Resilience deemed more relevant.	Pre-Post within group T1: M: 83:34 SD 9.64 T2: M:90.44 SD 10.90
Koni et al., 2019 B	Resilience Wagnild & Young R-15	25–125; higher = greater resilience	0.85	0.12	88	Resilience and social identity measures. Resilience deemed more relevant.	Pre-Post within group T1: M: 55.50 SD: 8.61 T2: M: 62.22 SD 7.23
Lown et al. (2023)	PROMIS	4-20; lower score = less anxiety	–	–	8	Very small sample size (n = 8) too small for meta-analysis	SWiM report only
McAnally et al. (2018)	Rosenberg Self-Esteem	0-30; higher = greater self-esteem	0.55	0.21	I:51 C:44	Self Esteem only relevant outcome	Quasi between group NBI T2 M: 22.2 SD 4.2 Control T2: M: 19.9 SD 4.0
McEwan et al. (2022)	POMS (Anxiety)	1-5 higher = more anxiety	0.32	0.16	44	Anxiety (POMS) only relevant validated measure.	Pre-Post within group M: 1.75 SD 0.63 M: 1.55 SD 0.60
Mutz & Müller 2016 PD	PSQ Worry Index	8–24; higher = greater stress	0.46	0.30	12	PSQ-worry only validated scale indexing psychological distress	Pre-Post within group T1: M:1.99 T2: M: 1.62 SDdiff: 0.81
Mutz & Müller 2016 MH	General Self-Efficacy Scale	10–40; higher = greater self-belief	0.24	0.29	12	GSES as other MH scale contained only 1 item. Study 2 not used due to age.	Pre-Post within group T1: M: 2.80 T2: M: 2.88 SDdiff 0.31
Rose et al., 2018 PD	EATQ-R Depression	Higher = greater depressive affect	0.61	0.09	150	EATQ-R most relevant validated clinical distress measure (vs aggression and fear)	Pre-post within group T2: M: 2.39 SD: 0.06 T3: M: 2.39 SD: 0.07
Rose et al., 2018 MH	Ryff Wellbeing composite	8-160 higher = greater wellbeing	0.46	0.09	150	Self-efficacy and Ryff wellbeing. Ruff wellbeing due to larger composite of wellbeing.	Pre-post within group T2: M: 82.28 SD 0.95 T3: M: 82.73 SD 1.00

(*continued on next page*)

Table C1 (*continued*)

Author (Year)	Domain/Outcome Measure	Scale range/scoring direction	g	se	n	Measure/Arm Reasoning	Study Design Time: Mean: SD:
Scarf et al. (2016)	Resilience Wagnild & Young R-15	15 items; higher = greater resilience	0.98	0.16	60	Resilience only relevant outcome T2 as T1 is one month prior	Pre-Post Within group (no control post results) T2: 81.18 SD: 9.37 T3: 90.80 SD: 10.02
Scarf et al. (2017)	Resilience Wagnild & Young R-15	15 items; higher = greater resilience	1.06	0.16	90	Resilience only relevant outcome	Quasi Between Group interaction effect reported. (η^2 to g conversion) $\eta^2 = 0.22$
Scarf et al., 2018 Study 1	Self-esteem Life Effectiveness sub-scale	3-24; higher = greater self esteem	0.33	0.16	I: 100 C: 73	Self-esteem and Group Belonging Self-Esteem as GB differs from social connection	Quasi Between group time × condition interaction (η_p^2 to g conversion) $\eta_p^2 = .027$
Scarf et al., 2018 Study 2	Self-esteem Self-Description Questionnaire III	8-62; higher = greater self esteem	0.38	0.16	I:80 C:91	Self-esteem, self-efficacy and group Belonging. Self-Esteem as GB differs from social connection and self-efficacy between group effects not reported.	Quasi Between group time × condition interaction (η_p^2 to g conversion) $\eta_p^2 = .035$
Sprague and Ekenga (2022)	Wellbeing HRQoL Emotional Functioning	1–5; higher = better functioning	1.79	0.15	I: 297 C: 65	HRQoL – 5 Domains. Emotional Functioning as it aligned closest to wellbeing	Quasi Between group NBI T2: 4.2 SD: 0.95 Control T2: 2.4 SD: 1.20
Tracey et al. (2018)	Kessler-10	10-50; lower score = less distress	–	–	9	Data and sample size too limited for meta analysis	SWiM analysis only
Whittington and Aspelmeier (2018)	Resilience AGRS	1–5; higher = greater resilience	0.25	0.04	708	Resilience only relevant outcome	Pre-Post between group T1: M: 4.05 SD: 0.47 T2: M: 4.17 SD: 0.50
Zeng et al. (2025)	Anxiety SCARED	0–82; higher = more anxiety	0.06	0.09	129	Anxiety and depression. Anxiety chosen as primary outcome of study.	Pre-Post between group T1: M: 25.73 SD 13.04 T2: M: 24.98 SD: 12.14

Note: MH = Mental Health; PD = Psychological Distress.

Appendix D

Table D1
Core Characteristics of NBIs

Author (Year)	Setting	Group Size	Duration	Frequency	Facilitator Type	Program Components
Albedry et al. (2023)	US high school; adventure education integrated into PE/ SEL	Class-based groups	15-week	Delivered across semester	School teachers/ adventure-ed staff	High ropes, rock climbing, hiking, camping and team-building games within a structured SEL course.
Allan et al. (2025)	UK residential outdoor centres across 10 sites	Large cohorts across centres	5-day residential	One 5-day camp	Outdoor adventure instructors/youth workers from NCS/Skills4Life	Camp-based experiences including mastering new skills, solving problems, group challenges, reflective activities, and being inspired by nature.
Arbuthnott and Sutter (2019)	Canadian outdoor camp plus school classroom comparison	Youth camp arm n = 15; classroom comparison n = 21	Multi-day residential camp	I: One camp C: Regular class	Camp staff and music facilitators	Guided hikes, campfires, nature/music discussion, group song writing, rehearsal and public performance.
Barton et al. (2016)	UK and South African wilderness locations	130 across 16 expeditions	5–11 days/ expedition	One expedition	Wilderness expedition leaders/outdoor educators	Total nature immersion with camping, hiking, canoeing, wild swimming, wildlife watching, foraging, journaling, solo time, leadership and teamwork tasks.
Bowen et al. (2016)	Australian outpatient mental health service + nearby wilderness	Clinical sample n = 36; delivered in therapy groups	10-week program	Multiple sessions over 10 weeks	Multidisciplinary mental health clinicians with WAT training	Youth-focused adventure/expedition activities, outdoor challenge, group processes, and structured therapy goals (prevention/early-intervention/ treatment focus).
Bowen & Neill (2016)	Australia; police–youth/school; wilderness + school follow-up	At-risk youth n = 53 (program group sizes NR)	6-day lead-in/ out + 9-day trip + mentor	Multi-phase over several months	Police-youth workers, outdoor adventure instructors + teachers	Catalyst program: 3-day/2-night preparation, 9-day outdoor adventure expedition, post-program follow-up days and school-based mentoring.
Choe et al. (2025)	Hong Kong urban park/nature area accessed via schools	I: 4-day group n = 33 C: Class-based n = 45	4–5 h per session	Four sessions over four days	University research team and school staff/teachers	Guided walking/hiking, sensory exploration, and mindfulness practice in nature to enhance nature connectedness and social health in park.
Dong et al. (2025)	China; school/ community outdoor space and indoor rooms	Outdoor n = 16; indoor plants n = 16; indoor n = 15	6 weeks	Weekly sessions + home practice	Qualified mindfulness instructors	Adolescent MBSR program delivered outdoors in nature, indoors with/ without plants, mindfulness practice plus encouraged home practice.

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Table D1 (*continued*)

Author (Year)	Setting	Group Size	Duration	Frequency	Facilitator Type	Program Components
Gabrielsen et al. (2019a)	Norway; coastal and forested wilderness near outpatient clinic	Therapy groups of 5–9 adolescents; total N = 32	8–10-week program	8 day outdoor + 3-day trip + 6-day trip	Interdisciplinary mental-health teams (3 per group) with outdoor competence	Out-patient wilderness therapy combining individual and group therapy with basic *friluftsliv* (Nordic outdoor life), camping, hiking and reflective activities.
Gabrielsen et al. (2019b)	Norway; coastal wilderness expeditions	Mixed-gender therapy groups 5–9; total N = 33	Core expedition phase 6–7 days	Daily sessions during multi-day expedition	Same interdisciplinary mental-health teams as above	Wilderness trips with progressive challenge: half-days, single-day hikes, 6–7-day expedition; daily group processes/reflection + measurement of anxiety.
Hignett et al. (2018)	UK coastal "blue-space" surf beaches and classroom	Baseline n = 58; surf groups smaller	12-week program	Sessions across a 12-week term (frequency NR)	GB Boardriders CIC surf coaches, school staff/youth workers	Surfing lessons, warm-ups and ocean sessions, plus classroom-based environmental education and wellbeing activities.
Keller et al. (2023)	USA; wooded area/ park near high school	Class group N = 24 (16 completed sessions)	3 weeks	Three 90-min sessions	ANFT-certified forest-bathing guide (teacher-researcher)	Guided forest bathing with sensory grounding, "partnership invitations", sit spot practice, and closing tea ceremony each session.
Koni et al. (2019) Study A	New Zealand; *Spirit of New Zealand* tall ship	Voyage cohort 30–40 with 10-person "watch" groups	10 consecutive days at sea	Continuous residential program	Ship's crew and youth-development/adventure-education staff	Sail-training voyage fostering new group identity; daily teamwork (sail handling, ship duties), mixed-gender watch groups, group reflections; no smartphones.
Koni et al. (2019) Study B	New Zealand; *R. Tucker Thompson* tall ship	Voyage cohort 30–40 with 10-person "watch" groups	7 consecutive days at sea	Continuous residential program	Ship's crew and youth-development staff with Māori cultural input	As above plus explicit emphasis on belonging and *whanaungatanga* (relationships), group identity activities, teamwork, and reflections; no smartphones.
Lown et al. (2023)	UK; remote wilderness (mountains/forests)	Very small clinical group, N = 8	9-day wilderness program	Single continuous 9-day expedition	Multidisciplinary; outdoor instructors, youth workers, psychosocial/medical staff;	SYATS 9-day wilderness therapy including hiking, outdoor skills training, camping, reflection, team building post-cancer treatment.
McAnally et al. (2018)	New Zealand; Tihoi outdoor campus vs standard school	Year-10 boys cohort divided into activity groups	15-week s at residential campus	4 class + 3 outdoor days per week	Residential teachers and outdoor-education instructors	Kayaking, tramping (backpacking), rock climbing, mountain biking, outdoor challenges; no phones/TV/ social media; plus, academic classes.
McEwan et al. (2022)	UK; urban park/ wooded area in London	Small groups of 6–15 per session	Single 1.5-h session	One guided session per participant	Two certified forest-bathing practitioners; Scout leaders present	Guided nature-connection walk including visual tree scans, "sound cupping", creative natural art, "interview a tree", partner/tree games and sharing circles.
Mutz & Müller (2016)	Germany Austria Italy Alpine route	Adolescent group n = 12	9 consecutive days	Daily full-day hiking (8 h/day)	Outdoor adventure leaders/educators	Alpine crossing with hiking (~1000 m ascent per day), shared accommodation, evening reflection sessions; Wi-Fi available but otherwise expedition-style living.
Rose et al. (2018)	Australia; three secondary-school outdoor camps in remote natural areas	Overall cohort n = 160 across three school program	5–9 day remote journeys	One multi-day camp per student	Outdoor education providers and school staff	Multi-day bushwalks and combinations of rafting, rock climbing, abseiling/ high ropes, mountain biking, canoeing/ sea kayaking, plus group reflection and camp life.
Scarf et al. (2016)	New Zealand; *Spirit of New Zealand* sailing ship	Voyage cohort 30–40 with 10-person "watch" groups	10 consecutive days at sea	Continuous residential 10-day voyage	Ship's crew and adventure-education leaders	Developmental sailing voyage with mixed-gender watch groups, rotating duties, 6am swims, progressive shift from crew-led to trainee-led operation, group reflections.
Scarf et al. (2017)	New Zealand; *Spirit of New Zealand*	Voyage cohort 30–40 with 10-person "watch" groups	10 days	Single 10-day voyage per participant	Ship's crew and youth-development staff	10-day tall-ship voyage with watch groups, daily sailing tasks and group debriefs; technology-free environment; focus on social connectedness and resilience.
Scarf et al. (2018)	New Zealand; *Spirit of New Zealand*	Voyage cohort 30–40 with 10-person "watch" groups	10 days	Single 10-day voyage per participant	Ship's crew and AEP instructors	10-day sail-training AEP; mixed-gender watch groups, collaborative ship tasks, structured opportunities to satisfy autonomy, competence, and relatedness needs.
Sprague and Ekenga (2022)	USA; low-income schools + parks, caves, rock-climbing gym	20-30 students/ class	15-week semester	45/90-min class + 4-day trips + 1 rock-climbing	Gateway to the Great Outdoors (GGO) educators plus classroom teachers	STEM and health/ecosystems/climate; inquiry projects; forest hikes, camping, canoeing, campfires, stargazing, litter clean-ups, cave tour and indoor rock-climbing.
Tracey et al. (2018)	Australia; school grounds and nearby park, beach, bushland	Small therapy group n = 9	8 weeks	Weekly sessions	Psychologist and outdoor/ adventure-education staff/ teachers	Acceptance and Commitment Therapy embedded in outdoor/adventure tasks (team challenges, hikes, problem-solving, trust games, nature-based metaphors).

(*continued on next page*)

Table D1 (*continued*)

Author (Year)	Setting	Group Size	Duration	Frequency	Facilitator Type	Program Components
Whittington and Aspelmeier (2018)	USA; single-gender camps in outdoors, forests, lakes, etc.	Large mixed sizes, cabin/activity groups smaller	3–49 days (mean 17.7 days)	Continuous residential camps	Camp counsellors, adventure-education staff and experiential educators	Adventure Education (small groups, novel/challenging tasks, cooperation/trust), Experiential Education, Traditional camp activities (arts, sports, swimming) and Mixed programs.
Zeng et al. (2025)	China; Ying River natural area ~200 m from rural school	Whole class/grade groups; total N = 129	Six sessions over 7 months	6 structured sessions	School teachers and mental-health/research staff (NR)	Nature play/walks, field observation, crafts, meditation, relaxation, expressive writing, psychodrama, guided imagery; group sharing and stress-management exercises.

Appendix E

Table E1
GRADE Summary Findings Table

Evidence Set	No. of Studies	Study Design	Pooled Effect	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall Certainty
Quasi-experimental mental health outcomes	7	Non-randomised with comparison group	0.82 [0.32–1.31]	Moderate–Serious	Very High (I^2 = 91.72 %)	Low	Low (adequate sample; CI precision acceptable)	Not detected (Egger p = .660)	Low ●●○○
Pre–post mental health outcomes	13	Single-group before–after	0.60 [0.36–0.85]	Serious–Critical	Extremely High (I^2 = 94.92 %)	Low	Moderate (CI width varied across samples)	Not detected (Egger p = .759)	Very Low ●○○○
Pre–post psychological distress outcomes	8	Single-group before–after	0.28 [0.04–0.52]	Serious–Critical	High (I^2 = 81.57 %)	Low	Moderate (smaller N; CI spans minimal effect)	Potential concern (Asymmetry; Fail-Safe N = 79)	Very Low ●○○○
SWiM (Narrative synthesis)	4	Uncontrolled/partial individual-level data	–	Critical	–	Low	Very serious (very small N; incomplete reporting)	–	Very Low ●○○○

Note: Legend: ●●●● High ●●●○ Moderate ●●○○ Low ●○○○ Very Low; Certainty ratings follow GRADE Working Group (2004) criteria. Each outcome was rated across five domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias. Pooled Effect *g* [95 % CI]).

Appendix F

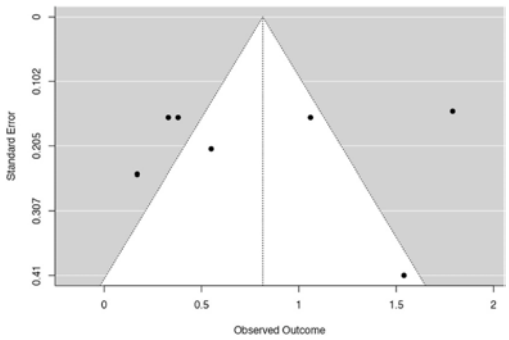

Fig. F1. Funnel Plot of Publication Bias – Quasi-experimental Studies

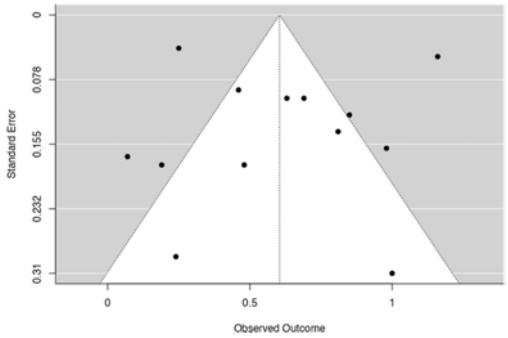

Fig. F2. Funnel Plot of Publication Bias – Pre-Post Studies Mental Health Outcomes

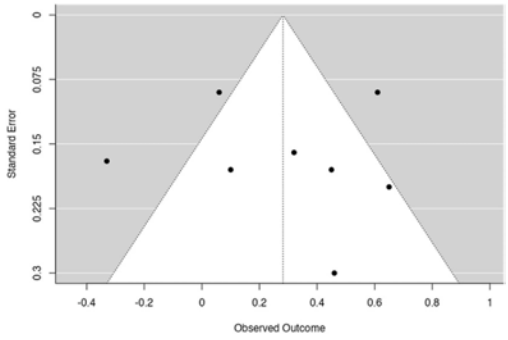

Fig. F3. Funnel Plot of Publication Bias – Pre-Post Studies Psychological Distress Outcomes

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