Educational Psychology Review (2024) 36:133
https://doi.org/10.1007/s10648-024-09963-1

REVIEW ARTICLE

Effects of School-led Greenspace Interventions on Mental, Physical and Social Wellbeing in Children and Adolescents: A Systematic Review

Vi Ly[1] · **Dianne A. Vella-Brodrick**[2]

Accepted: 14 October 2024

Abstract

Promoting children's and adolescents' mental, physical, and social wellbeing is highly important to help them learn, create social connections, and stay healthy. Nature has the potential to restore cognition, reduce stress and mental fatigue, and improve wellbeing, all factors that are conducive to learning. There is growing interest in understanding the effects of nature on the wellbeing of children and adolescents, particularly in the school context. This paper presents a PRISMA-guided systematic review of the literature examining the effects of school-led nature interventions on the mental, physical, and social wellbeing of school children and adolescents aged 5 to 19 years. Examples of school-led nature interventions include outdoor learning, walks in nature and green schoolyards. Experimental and quasi-experimental studies employing quantitative measures were selected, yielding 19 studies from 17 papers. Included studies were rated as being of high ($n=6$) and moderate quality ($n=13$). The results provide some evidence that nature exposure in the school context can improve the wellbeing of children and adolescents, particularly their positive affect, physical activity, and social relationships/interactions. The wellbeing effects of school-led nature interventions were also examined according to age and gender, with results indicating a gender effect, but inconclusive findings for age. Findings from this review support the integration of nature in schools to enhance the mental, physical and social wellbeing of children and adolescents.

Keywords Nature · Students · Outdoor education · Natural environments

✉ Dianne A. Vella-Brodrick
dianne.vella-brodrick@unimelb.edu.au

[1] Faculty of Education, University of Melbourne, Melbourne, VIC, Australia

[2] Centre for Wellbeing Science, Faculty of Education, University of Melbourne, Melbourne, VIC, Australia

Published online: 11 November 2024

Introduction

The growing shift towards an urbanised society has been associated with a decrease in nature exposure, particularly among children, who have also displayed an increase in digital gaming and electronic use (Yin et al., 2022). Coinciding with the rise in urbanisation and high density living, there has been an increase in the prevalence of mental health disorders, and health problems such as asthma, obesity and diabetes (Godfrey & Julien, 2005; Whiteford et al., 2013). Mental health disorders affect approximately 13% of children and adolescents worldwide (Polanczyk et al., 2015). In addition, a decline in physical fitness has been observed among children and adolescents in recent years (Fuhner et al., 2021; Masanovic et al., 2020). Thus, interventions to promote the wellbeing of young people are needed. Examining the effects of nature on wellbeing is a promising area of research (Berman et al., 2012; Bowler et al., 2010; Bratman et al., 2015; Cox et al., 2017; Menardo et al., 2021).

Nature (or natural environments) can be broadly defined as including "living plants and animals, geological processes and weather"; and nature exposure commonly encompasses "connecting with 'green' and 'blue' spaces including park land, forests, plants, the ocean or other natural waterways such as rivers and lakes" (Vella-Brodrick & Gilowska, 2022, p. 1218). Greenspace has been well documented recently in the literature. Various definitions of greenspace (or green space) exist, but typically it is defined as comprising of vegetation and is associated with natural 'green' elements (Taylor & Hochuli, 2017). For simplicity, when the term 'nature' is used in this systematic review, this will refer to 'greenspace'. In the adult population, nature exposure has been associated with increased positive affect and decreased negative affect (McMahan & Estes, 2015), improved mood (Berman et al., 2012), increased physical activity (Kaczynski & Henderson, 2007), and stress recovery (Ulrich et al., 1991). As positive wellbeing effects have been associated with nature exposure, the next section will present some of the key theoretical perspectives on the human-nature connection. Following this, the review will focus on the impact of school-led nature interventions on the mental, physical and social wellbeing of children and adolescents, including a summary of previous review findings.

Theories on Nature and Human Health

A number of theories have been suggested to explain the relationship between nature and human health. The Biophilia Hypothesis suggests that humans have an innate tendency to seek connections and affiliate with nature for survival and psychological restoration (Wilson, 1984). As human evolution occurred through interactions with natural environments, it is proposed that humans carry a biological-based biophilic tendency (Kellert & Wilson, 1993). Therefore, when an interaction with nature is made, there is an opportunity for humans to replenish their cognitive capacity and enhance their wellbeing. Two theories that complement the Biophilia Hypothesis are the Attention Restoration Theory and Stress Reduction Theory.

The Attention Restoration Theory (ART) posits that exposure to nature provides a restorative effect by recovering directed (effortful) attention after prolonged mental activity (Hartig et al., 1997). Natural environments (compared to urban

environments) are likely to contain restorative qualities that elicit (effortless) *fascination*, which allows for the renewal of cognitive resources (Kaplan, 1995; Kaplan & Kaplan, 1989). To be restorative, nature also needs to provide a sense of *being away*, it must have *extent* (i.e., scope to feel immersed and engage the mind), and it must be *compatible* with one's purposes and inclinations (Kaplan, 1995). The Stress Reduction Theory (SRT) proposes that natural environments have a restorative effect that reduces physiological stress and negative emotions (Ulrich, 1983). This theory suggests that following a stressful situation, exposure to unthreatening natural environments provides a calming effect, which reduces arousal and promotes positive feelings (Ulrich et al., 1991). Therefore, consistent with the Biophilia Hypothesis, these two theoretical perspectives offer a common theme, wherein nature provides opportunities for restoration to occur by reducing mental fatigue and stress, which in turn enhances wellbeing. These two theories also have a range of empirical support (e.g., Berto, 2005; Lee et al., 2015; Ulrich et al., 1991; Yao et al., 2021). It is therefore possible that nature exposure in educational settings can help to improve students' wellbeing for optimal learning experiences. The broad aim of this paper is to undertake a systematic review to examine the effects of school-led nature interventions on mental, physical and social wellbeing outcomes of children and adolescents, and to examine the age and gender influences in this relationship.

Impact of Nature on Mental Wellbeing Among Children and Adolescents

Mental wellbeing can be defined as "a state in which humans can understand their potential, work productively, manage the stress of life, and participate in society" (Jabbar et al., 2022, p. 4415). In research, 'mental wellbeing' is often used as an umbrella term, encapsulating different variables such as anxiety, depression, stress, quality of life, life satisfaction, affect, self-concept, and resilience (Liu & Green, 2023; Mygind et al., 2019; Rowley et al., 2022; Zhang et al., 2020). This review will focus on the concepts of positive and negative affect, and stress reduction and restoration. These variables were selected because affect (defined as a person's internal state associated with their emotions; Barrett & Bliss-Moreau, 2009) and stress reduction are commonly researched in the literature regarding nature exposure on youth outcomes (Rowley et al., 2022).

Research on the effects of nature on children's and adolescents' mental wellbeing are emerging. For example, Passy (2014) found that primary-school students ($n=87$) reported that simply viewing the school garden generated feelings of happiness, wherein the garden made students feel 'good' and 'joyful' (p. 31; 32). Dopko et al. (2019) found that primary school children reported significantly greater positive affect when they were at a nature school compared to when they visited a museum. Surprisingly, the children also reported significantly greater negative affect when they were at the nature school compared to the museum (Dopko et al., 2019). Kelz et al. (2015) investigated the influence of schoolyard greening on adolescents' ($n=133$) physiological stress levels, as measured by blood pressure. The intervention school underwent a schoolyard renovation to include greenspace (e.g., shrubs, plants) while the control school did not undergo a schoolyard redesign. Data were

collected before, and 6–7 weeks after the installation of the new green schoolyard. It was found that blood pressure levels were lower at post-intervention for students in the intervention school, suggesting a reduction in stress, compared to the control school. In another study, Dettweiler et al. (2017) compared the stress levels of students experiencing an outdoor curriculum in a forest (intervention group; IG) and a normal school setting (control group; CG). Stress levels were measured by cortisol, using saliva samples collected throughout the day. Cortisol is commonly seen as a stress hormone, with high cortisol levels indicating high stress levels (Chojnowska et al., 2021). Forty-eight students were allocated to either the IG (n = 37) or CG (n = 11). The results showed that cortisol levels significantly declined over the school day for students in the IG compared to the CG. Overall, it can be observed that experimental studies regarding the impact of school-led nature interventions on children's and adolescents' mental wellbeing are emerging, however, a critical appraisal of the study quality is needed to determine the level of confidence placed on the conclusions drawn.

Impact of Nature on Physical Wellbeing Among Children and Adolescents

Physical wellbeing can be defined as "a balanced state of the human body with its lifestyle, having choices to ensure health" (Jabbar et al., 2022, p. 4413). In research, 'physical wellbeing' has been used as an umbrella term to encapsulate different variables, such as physical fitness, physical activity, and body mass index (BMI; Jabbar et al., 2022; Mygind et al., 2019). This systematic review will focus on Physical Activity (PA) because this variable is commonly examined in research on nature exposure and young people (e.g., Dyment & Bell, 2008). As it is commonly researched, this allows for a comprehensive review to be conducted.

Research on the effect of school-led nature interventions on children's PA have been mixed. Observational research by Pawlowski et al. (2016) reported that school greenspace was associated with greater PA among 10 to 13-year-olds compared to asphalt-paved and indoor areas. A case study by Mygind (2007) examined the impact of a forest school day on children's PA levels. Based on data from 19 children (aged 9–10 years), the results showed no significant differences in mean PA levels between a forest school day and a traditional school day. Nevertheless, when looking at experimental studies, the abovementioned study by Dettweiler et al. (2017) also examined the impact of the outdoor curriculum on students' PA levels. As previously mentioned, students were taught using an outdoor curriculum in a forest (IG) or an indoor classroom (CG). The researchers found that students who were taught in the forest showed higher PA levels than their peers in the classroom. However, in another study, the impact of weekly forest school days on students' (aged 7–9 years) PA levels was non-significant when compared to regular school days (Trapasso et al., 2018). Due to the mixed findings regarding the effectiveness of school-led nature interventions on students' PA levels, conducting a systematic review would provide valuable insight into some of the underlying mechanisms that could be contributing to these differences.

Impact of Nature on Social Wellbeing Among Children and Adolescents

Social wellbeing can be broadly defined as "a state in which humans can coexist peacefully in communities with opportunities for advancement" (Jabbar et al., 2022, p. 4417). Researchers have referred to social wellbeing through sub-categories such as social relationships, social belonging, social support, social anxiety, and pro-social behaviours (Becker et al., 2017; Mygind et al., 2019). This review will focus on social interactions and relationships, and pro-social behaviour (defined as a 'positive' social behaviour intended to benefit the welfare of others; Pfattheicher et al., 2022). These variables were selected because they are also commonly researched in the literature focusing on young people and nature exposure (Mygind et al., 2019).

Experimental studies on the impact of school-led nature interventions on children's and adolescents' social wellbeing vary in quality. For example, Rose et al. (2018) examined whether a school camp in nature was associated with improvements in adolescents' social wellbeing. One hundred and sixty secondary-school students completed wellbeing questionnaires before and after camp, and results showed an increase in peer connectedness (i.e., relationships between classmates) among students after camp, whereas no significant differences were found for students' friend connectedness (i.e., relationships with existing friends). The friend connectedness outcome is surprising, given that peer connectedness improved, however, Rose et al. attributed this finding to the students being placed in small groups without their friends during camp. Thus, friendships were maintained but not significantly enhanced. This study highlights that school nature camps may encourage adolescents to build new interpersonal bonds. However, while pre-post measures were assessed, there was no control group to compare the changes, making it difficult to determine whether nature exposure or other factors (e.g., the novel experience of attending camp) caused these changes. Furman and Sibthorp (2014) examined the impact of a 14-day outdoor education program on adolescents' (aged 14-15 years) pro-social behaviour. Students in the IG participated in environmental education programs consisting of guided activities in nature. Students in the CG attended traditional classes. Pre- and post-intervention questionnaire data from participants showed a non-significant difference in pro-social behaviour between the IG and CG. However, various activities were implemented in the IG (but not the CG; e.g., journaling, reflections), making it difficult to determine whether the results were due to nature or the additional activities included. Hence, research on the impact of nature on young people's social wellbeing would benefit from having the study quality evaluated to determine the level of bias in current research.

Findings from Previous Reviews

More recently, systematic reviews have been conducted to gain a better understanding of the relationship between nature and wellbeing among children and adolescents (Bikomeye et al., 2021; Mann et al., 2022; Mygind et al., 2019; Roberts et al., 2020; Rowley et al., 2022; Zhang et al., 2020). For example, Roberts et al.'s (2020)

systematic review containing 14 studies investigated the impact of nature contact on children's and adolescents' wellbeing. They found improvements in self-esteem, confidence, positive affect, stress reduction and restoration, resilience, and social benefits from nature exposure. Similarly, Mygind et al.'s (2019) systematic review of 84 studies also found some support for improvements in self-esteem, self-efficacy, resilience, academic and cognitive performance, and PA from nature exposure among children and adolescents. Although previous reviews have been conducted, there are some noteworthy gaps in the literature. For example, systematic reviews exploring the impact of nature on children's and adolescents' wellbeing often include a wide range of nature interventions, such as residential greenspace, neighbourhood parks, and school greenspace (e.g., Mygind et al., 2019; Roberts et al., 2020; Vanaken & Danckaerts, 2018; Zhang et al., 2020). While this provides advantages in that it captures the potential settings where greenspace can be incorporated to improve children's and adolescents' wellbeing, differences in the impact of nature between settings have been found (e.g., see Vanaken & Danckaerts, 2018). This makes it difficult to ascertain whether factors such as demographic characteristics (e.g., family affluence) or social factors (e.g., neighbourhood perceptions), have a greater impact on wellbeing than greenspace, thus confounding the results (e.g., Huynh et al., 2013).

As greenspace may not be easily accessible for some students outside of school, including greenspace in schools bridges the health equity gap by providing all students, such as students from low-income, urban neighbourhoods lacking in greenspace, with safe natural spaces for play opportunities (Bikomeye et al., 2021). Schools, being largely compulsory, are ideally placed to facilitate nature activities that students may not otherwise experience (Miller et al., 2021). Even if the nature intervention is not located within school grounds, schools may provide nature programs for students (e.g., school field trips in nature). As no firm conclusions have been drawn concerning the impact of school-led nature interventions on children's and adolescents' wellbeing, more research is needed to collate the findings in this area to better understand the wellbeing effects. Therefore, this paper aims to systematically review the literature, on the impact of *school-led* nature interventions on children's and adolescents' mental, physical and social wellbeing outcomes.

Age and Gender

Age and gender differences may also influence the relationship between school-led nature exposure and children's and adolescents' wellbeing. The effects of age and gender have been primarily researched in relation to PA among the youth population. For example, studies have found that PA decreases with age, with younger children (i.e., Grades k-4) being more physically active than older children (i.e., Grades 5–8; Bates et al., 2018; Sherar et al., 2007). It is possible that as children get older, changes in schoolwork demands and less opportunities for organised play are contributing to this PA decline (Belanger et al., 2011). It has also been reported that women are less active than men (Ball et al., 2015). However, when viewing the influence of gender in the relationship between schoolyard greenspace and students'

PA levels, a gender effect may be present. For example, Dyment et al. (2009) investigated the relationship between schoolyard designs and children's PA levels. They found that girls were more likely to exert PA in areas that promoted open-ended play (e.g., greenspace), while boys were gravitated towards areas that promoted sport-based, rule-bound activities (e.g., hardscapes). In addition, Bikomeye et al.'s (2021) systematic review found that school greenspace benefits younger children and girls more than older children and boys on some PA outcomes. However, less is known on the age and gender effects of mental and social wellbeing outcomes from school-led nature interventions. Research on this is needed because examining the age and gender effects will be important to determine how to best support the wellbeing of all students. Thus, this systematic review will also examine whether the impact of school-led nature interventions on mental, physical and social wellbeing outcomes, differ according to age and gender, among children and adolescents.

In this paper, *school-led nature interventions* will be defined as a nature (greenspace) intervention that is conducted by the school (i.e., school-led), and it can be located either within (e.g., school garden) or outside school grounds (e.g., outdoor classrooms conducted in the forest). We will focus specifically on experimental and quasi-experimental studies, to enable insights to be gained from high quality studies with rigorous designs.

This systematic review aims to answer the following research questions:

1) What are the effects of school-led nature (greenspace) interventions on mental, physical and social wellbeing outcomes for school-aged children and adolescents?
2) Do these effects of school-led nature interventions on mental, physical, and social wellbeing differ according to age and gender?

Method

An a priori protocol was designed and registered with PROSPERO (registration number: CRD42023417162). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were applied to guide the systematic review process. This began with using the PICOS (Population, Intervention, Comparison, Outcome, Study design) model to develop the main research question and to determine the appropriate search terms. The main research question based on the PICOS population, intervention and outcome was: What are the effects of school-led nature interventions on mental, physical and social wellbeing outcomes for school-aged children and adolescents? Key components included school-led nature interventions on selected wellbeing outcomes, focused on school children and adolescents, and the inclusion of experimental and quasi-experimental studies (see Tables 1 and 2). By including only experimental and quasi-experimental studies, this review aimed to identify the causal relationship of school-led nature interventions on the selected wellbeing outcomes, so that the interventions' effectiveness can be determined with a high level of confidence.

Table 1 PICOS concepts and key terms

PICOS	Concepts	Keywords/Search terms
P (Participants)	School-going children and adolescents aged 5–19 years	School environment, school landscape*, school-based, childhood, child*, adolescent*, adolescence, student*, teenage*
I (Intervention)	School-led nature (greenspace) exposure intervention	green break, green area, view* of nature, nature view*, nature exposure, nature walk, exposure* to nature, outdoor*, greening, greenspace, nature intervention
C (Comparison)	Urban, classroom, control condition	—-
O (Outcome of interest)	**Mental wellbeing:** - Positive affect - Negative affect - Stress reduction/stress restoration **Physical wellbeing:** - Physical activity **Social wellbeing:** - Social relationships/interactions - Pro-social behaviour	Positive affect, emotions, happiness, negative affect, stress reduction, stress restoration Physical activity, exercise, fitness Social interactions, Social connectedness, Social relationships, Pro-social behaviour
S (Study design)	Experimental or quasi-experimental designs	—-

Table 2 Study selection criteria

	Include	Exclude
Date	No limit	——
Geographic location of study	No limit	——
Language	Studies written in English	Studies not written in English
Participants	School-going children and adolescents aged 5–19 years from the general student population	Participants younger than 5 or older than 19 years and who are not attending primary or secondary school
Peer review	Published empirical peer-reviewed articles	Studies not peer-reviewed
Reported outcome variables	**Mental wellbeing:** - Positive affect - Negative affect - Stress reduction/stress restoration **Physical wellbeing:** - Physical activity **Social wellbeing:** - Social relationships/interactions - Pro-social behaviour Outcomes reported using standardised and validated assessments/ questionnaires	If study does not include any of the outcome variables
Intervention	Study intervention can be of any duration, and located inside or outside of school grounds, but it must be a school-led nature (greenspace) intervention	Interventions that are not both nature-based (greenspace) and school-led
Study design	Experimental Quasi-experimental Quantitative studies	Case studies Qualitative studies Correlational design

Search queries were based on a combination of keywords (see Table 1). Consistent with a previous systematic review (Vella-Brodrick & Gilowska, 2022), the search terms targeted papers on nature/greenspace interventions combined with each of the selected wellbeing outcomes, among children and adolescents. Searches for the mental, physical and social wellbeing categories were completed separately. An example of a search for the effect of school-led nature interventions on mental wellbeing for children and adolescents in Scopus was: TITLE-ABS-KEY("school environment" OR "school landscape*" OR "school-based" OR "childhood" OR "child*" OR "adolescent*" OR "adolescence" OR "student*" OR "teenage*") AND TITLE-ABS-KEY("green break" OR "green area" OR "view* of nature" OR "nature view*" OR "nature exposure" OR "nature walk" OR "exposure* to nature" OR "outdoor*" OR "greening" OR "greenspace" OR "nature intervention") AND TITLE-ABS-KEY("positive affect" OR "emotions" OR "happiness" OR "negative affect" OR "stress reduction" OR "stress restoration").

The searches were conducted in April 2023 through the following data-bases: Scopus, PsycINFO, ERIC, and Medline. These data-bases were selected as they contain articles relevant to the research topic. A total of 5431 papers were found (see Fig. 1). All duplicates were removed, which reduced the results to 3461 articles. The screening process started with removing irrelevant papers based on title and abstract ($n = 3386$). The first author conducted the title-abstract screening process, consulting with the second author at several stages to test out the inclusion–exclusion criteria. Subsequently, the title-abstract screening process resulted in 75 articles moving through to the full-text review stage. The full-text review stage consisted of the first author carefully evaluating all 75 studies according to the inclusion–exclusion criteria (see Table 2). Out of the 75 studies in the full-text review stage, the second author independently reviewed 15 of the studies (20%), and as there was full agreement between the authors on the eligibility of these 15 studies, it was determined that the first author would review the remaining studies. The first author consulted with the second author at several stages throughout this process, and a consensus was achieved regarding the full-text eligibility of the studies. In the case of disagreements, this was settled by discussions between the two reviewers. Seventeen papers comprising of 19 studies were selected for the systematic review. Reasons for the full-text exclusions are presented in the PRISMA flowchart (see Fig. 1).

The following information was extracted from the selected studies: author, year of publication, location, sample characteristics (size, age, gender), study design, details of nature intervention and control/comparison groups, wellbeing outcomes assessed, the measures, the frequency of assessments, and the efficacy of the intervention (see Table 3).

Quality Appraisal of the Studies

An appraisal of the quality of the included studies in the review was based on the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (Effective Public Healthcare Panacea Project, 2023). The EPHPP tool is considered to be a reliable quality assessment tool (Armijo-Olivo

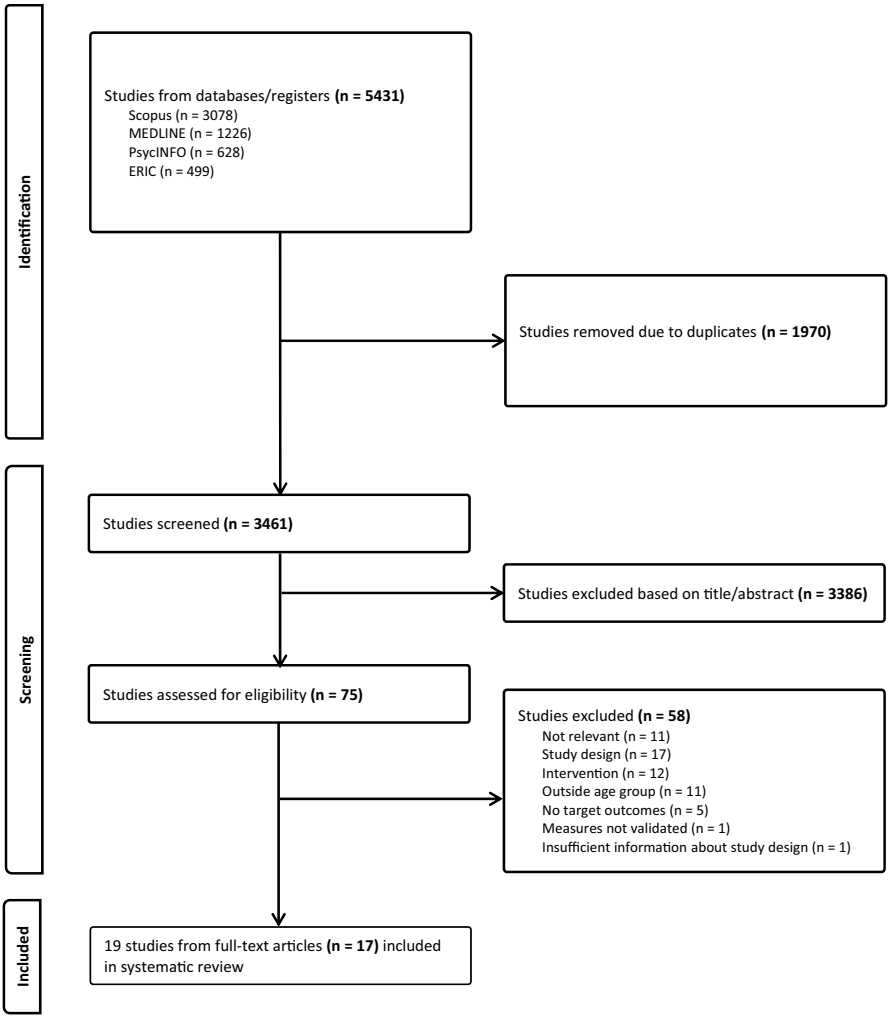

Fig. 1 PRISMA flowchart

et al., 2010), that is suitable for use in systematic reviews of effectiveness (Deeks et al., 2003; Jackson & Waters, 2005). The EPHPP tool assesses study quality in six domains (selection bias, study design, confounders, blinding, data collection methods, withdrawals and dropouts). These domains are rated as 1 (strong), 2 (moderate) and 3 (weak) according to a standardised guide and dictionary. The overall rating of study quality involves averaging the scores of the six domains. Using the EPHPP checklist and dictionary, both authors independently appraised the quality of all 19 studies. In the case of differing ratings between reviewers, each explained their reasons for their selection and when discrepancies were still present, a third person who was experienced with using the EPHPP tool was consulted and a consensus about the ratings was achieved.

Table 3 Characteristics of selected studies

Author, Year, Country	Study design	Sample size	Sample characteristics	Intervention/Comparison	Outcome and Data source	Timing of assessment	Main findings
Bolling et al. (2021) Denmark	Quasi-experimental – Between Groups	617	Primary school students in grades three to six; Mage = 10.9 years; 341 girls (55%)	EOtC lessons in greenspace (e.g., forest) vs. non-greenspace EOtC vs. school-ground EOtC vs. traditional school day	PA: Accelerometers	Accelerometer data were measured continuously for 10 days	No significant difference in PA between EOtC in greenspace and traditional school day No significant sex differences in PA between the conditions
Dettweiler et al. (2017) Germany	Quasi-experimental – Between Groups, Repeated Measures	48	5th and 6th grade students; Mage = 11 years; 18 girls (38%)	Outdoor teaching (one school day per week in a forest) vs. traditional classes without outdoor teaching (control)	Stress: Salivary cortisol PA: Accelerometers	Data were collected at three time points throughout the day, over a school year	Students in outdoor teaching had increased PA, and greater decline in cortisol throughout the day (suggesting stress reduction), compared to control group participants
Finn et al. (2018) USA	Experimental – Repeated Measures	44	Primary school children; Ages 9–10 years; 25 girls (57%)	A five-day, five hour per day, outdoor education program in nature	PA: Pedometers -Accelerometers	Pre-intervention; Post-intervention	PA was significantly higher during outdoor education compared to a typical school day (pre-intervention)
Greenwood and Gatersleben (2016) UK	Experimental – RCT; Between Groups	120	Secondary school students; Ages 16–18 years; 66 girls (55%)	School grassed area with trees, shrubs, flowers vs. small room with no view of nature; Three contexts: time alone vs. with peers vs. mobile phone game (20 min in one of the six conditions)	Stress: -Heart rate -Blood pressure Positive Affect: - ZIPERS	Immediately after stressor tasks; Post-intervention	Non-significant differences between outdoor and indoor environment for heart rate and blood pressure (reduced in all conditions) Increased positive affect in the outdoor environment compared with a reduction in positive affect in the indoor environment
Harvey et al. (2021) UK; Study 1	Experimental – Repeated Measures	443	Primary and Secondary students in Years 2–13; Age range = 6–18 years	Biodiversity Project: Spending an hour a week, for 21 weeks, in the school nature grounds, monitoring and improving biodiversity	Positive Affect: PANAS-C	Pre-intervention; Post-intervention	Mood significantly improved from pre- to post-intervention

Table 3 (continued)

Author, Year, Country	Study design	Sample size	Sample characteristics	Intervention/Comparison	Outcome and Data source	Timing of assessment	Main findings
Harvey et al. (2021) UK; Study 2	Experimental – Repeated Measures	105	Primary and Secondary students in Years 1–9; Age range = 5–14 years	BioBlitz: A one-hour activity searching for wild flora and fauna in school grounds	Positive Affect: PANAS-C	Pre-intervention; Post-intervention	Positive mood significantly improved from pre- to post-intervention
Mårtensson et al. (2014) Sweden	Quasi-experimental – Between Groups	187	4th (10–11 years) and 6th (12–13 years) grade students at two schools	Open grass fields and woodland school (Green school) vs. paved and gravel school (Grey school)	PA: Pedometer	Data collected throughout the day for one week	No significant differences in PA between Green and Grey school. Boys had significantly more PA than girls at both schools. No significant difference in PA between ages (4th vs. 6th grade)
Mason et al. (2022) Italy	Experimental – Repeated Measures	65	2nd and 3rd grade students from two primary schools; Mage = 8.3 years; 30 girls (46%)	School lesson taught in green school garden vs. indoor classroom	Positive and Negative Affect: PANAS	Participants reported their affect before and after a lesson in school garden; and before and after an indoor classroom lesson	No significant main effect of setting on positive and negative affect. However, students with high emotional difficulties increased in positive affect after the green lesson compared to the indoor lesson. Positive affect for students with low emotional difficulties did not differ between settings. This moderating effect was non-significant for negative affect
Pagels et al. (2014) Sweden	Quasi-experimental – Between Groups, Repeated Measures	196	2nd, 5th, and 8th graders from four schools; Age range = 7–14 years; 88 girls (45%)	1 – schoolyard with artificial grass; 2 – schoolyard with woodlands; 3 – schoolyard with paved/gravel surfaces; 4 – schoolyard with play equipment	PA: Accelerometer	Data collected during 5 consecutive school days on three occasions during school year	Students in schools with schoolyards covered in artificial grass or woodlands spent significantly more time in PA than students in the paved gravel or play equipment schoolyards. Boys spent more time in PA than girls. 2nd graders were more physically active than 5th and 8th graders

Table 3 (continued)

Author, Year, Country	Study design	Sample size	Sample characteristics	Intervention/Comparison	Outcome and Data source	Timing of assessment	Main findings
Peacock et al. (2021) USA	Experimental – Repeated Measures	69	4th grade students from five primary schools; Age range = 9–10 years; 48% girls	Outdoor education program at a local nature camp	PA: Accelerometers	Pre-intervention; Post-intervention	PA was significantly higher in outdoor education than indoor education (pre-intervention) No significant PA differences between gender
Pirchio et al. (2021) Italy Study 1	Quasi-experimental – Between Groups, Repeated Measures	407	Students from six primary and secondary schools; Age range = 9–11 years; 54.1% boys	Environmental education program (three visits to nature reserve) vs. control group who did not take part in the program	Pro-social behaviour: 4 items from the Perceived Social Self-Efficacy Scale	Pre-intervention; Post-intervention	Non-significant differences in pro-social behaviour between experimental and control group, from pre- to post-intervention
Pirchio et al. (2021) Italy Study 2	Quasi-experimental – Between Groups, Repeated Measures	338	Students from six primary and secondary schools; Age range = 9–11 years; 48.8% boys	Environmental education program (three visits to nature reserve) vs. control group who did not take part in the program	Pro-social behaviour: 4 items from the Perceived Social Self-Efficacy Scale	Pre-intervention; Post-intervention	Non-significant differences in pro-social behaviour between experimental and control group, from pre- to post-intervention
Raney et al. (2019) USA	Quasi-experimental – Between Groups, Repeated Measures	437	Two primary schools; Students in 1st to 5th grade	Experimental school had schoolyard greening renovation (e.g., added trees, mulch, grass) vs. control school had no schoolyard renovation (e.g., paved)	PA: SOPLAY Social interactions - SOCARP	Pre-intervention; Post-intervention; 4-month follow-up	In the experimental school, an increase in PA from pre- to post-intervention. In the control school, no significant differences in PA from pre- to post-intervention For social interaction: anti-social interaction rates decreased significantly at 4-month follow-up compared to pre-intervention at the experimental school only

Table 3 (continued)

Author, Year, Country	Study design	Sample size	Sample characteristics	Intervention/Comparison	Outcome and Data source	Timing of assessment	Main findings
Raney et al. (2021) USA	Quasi-experimental – Between Groups, Repeated Measures	330	Two primary schools; Students in 1st grade to 6th grade; 168 girls (51%)	16-Month follow-up of Raney et al. (2019). See intervention above	PA: SOPLAY- Accelerometer Social interactions: SOCARP	16 months follow-up	At 16-month follow-up, students in the experimental school had significantly higher PA than students in the control school For social interaction, anti-social interactions were less frequent in experimental school participants relative to baseline. No significant difference for the control school over time
Romar et al. (2019) Finland	Experimental-Repeated Measures	21	Students from 1st grade to 6th grade in primary school; 10 girls (48%)	Outdoor learning in the forest vs. traditional indoor school lessons	PA: Accelerometers	Data collected over 2 weeks; 4 days of traditional teaching and 5 days of outdoor-learning	During outdoor-learning days, there was an increase in PA among students, compared to traditional school days
Trapasso et al. (2018) UK	Experimental – Repeated Measures	59	Primary school children; Age range = 7–9 years; Mage = 8.2 years; 26 girls (44%)	Weekly forest school (FS) day vs. regular school day (without PE) vs. regular school day (with PE). (12 weeks)	PA: Accelerometers PAQ-C	Accelerometer data collected for seven consecutive days during week 6 (included one FS day) PAQ-C data collected at baseline and at 12-weeks	No significant differences in children's self-reported PA between baseline and 12-weeks (PAQ-C data) For accelerometer data, no significant differences between conditions on the total PA levels Boys had significantly greater PA levels than girls

Table 3 (continued)

Author, Year, Country	Study design	Sample size	Sample characteristics	Intervention/Comparison	Outcome and Data source	Timing of assessment	Main findings
Van Dijk-Wesselius et al. (2018) The Netherlands	Quasi-experimental – Between Groups, Repeated Measures	2031	Primary school children; Age range = 7–11 years	5 schools greened their schoolyards (included grassy hills, bushes, trees, garden) vs. 4 control schools with paved schoolyards	PA: Accelerometers Pro-social behaviour:SOCC, Pro-social subscale of the Strength and Difficulties Questionnaire Social relationships: A subscale of a validated Dutch instrument measuring social functioning	Baseline; 1st Follow-up; 2nd Follow-up	No significant interactions between time (baseline, follow-up 1, follow-up 2) and condition (intervention, control) were found for PA. However, girls in the intervention schools increased in PA from baseline to follow-up 1, while girls in the control schools did not. No significant impact of greening schoolyards on PA for boys For pro-social behaviour, no significant interactions between time (baseline, follow-up 1, follow-up 2) and condition (intervention, control) Self-reported social relationships improved for children in the intervention schools from baseline to follow-up 1 and 2, compared to control schools
Wells et al. (2014) USA	Experimental – RCT; Between Groups, Repeated Measures	227	Primary school students in grades 4–5; Age range = 8–12 years; Mage = 9.3 years; 128 girls (56.4%)	School garden intervention vs. waitlist control	PA: Accelerometers PARAGON	Baseline (wave 1); Post-intervention in three waves: late spring 2012 (wave 2); fall 2012 (wave 3); late spring 2013 (wave 4)	Students with garden interventions showed a significant increase in PA from wave 1, to waves 2,3, and 4, compared to control condition Direct observation (PARAGON) showed that children were more active during outdoor garden lessons than indoor lessons

Table 3 (continued)

Author, Year, Country	Study design	Sample size	Sample characteristics	Intervention/Comparison	Outcome and Data source	Timing of assessment	Main findings
Wood et al. (2014) UK	Experimental – Randomised and Counterbalanced Repeated Measures	25	Primary school children; Age range = 8–9 years; Mage = 8.6 years; 13 girls (52%)	Playing in the school field (greenspace) vs. playground (concrete areas)	PA: Accelerometers	Data collected over 2 weeks, during morning and lunch playtime on the final two days of each week	Both boys and girls increased in PA on the green field compared to the playground PA was higher in boys than girls in both environments

Note. *PA* = physical activity. *EOtC* = education outside the classroom. *ZIPERS* = Zuckerman's inventory of personal reactions. *PANAS* = positive and negative affective scale. *PANAS-C* = positive and negative affective scale-children. *SOPLAY* = system for observing play and leisure activity in youth. *SOCARP* = system for observing children's activity and relationships during play. *PAQ-C* = physical activity questionnaire for older children. *SOCC* = social orientation choice card. *PARAGON* = physical activity research and assessment tool for garden observation.

Results

Study Characteristics

A total of 19 studies from 17 journal articles were selected for inclusion in this review. The studies were mainly from Europe ($n=14$; 74%), with the remainder from the United States ($n=5$; 26%). Study designs included repeated-measures ($n=8$), between-groups ($n=3$), and a combination of between-groups and repeated-measures ($n=8$). A variety of statistical analyses were applied across studies, such as linear-mixed models, multilevel models, ANOVA, ANCOVA, and t-tests. Sample sizes varied substantially from 21 to 2031 participants. The study population included children (age 5–12 years) and to a lesser extent, adolescents (age 13–19 years). The majority of studies examined the childhood population ($n=14$). Some studies examined a combination of children and adolescents ($n=4$), and adolescents only ($n=1$). All studies included male and female participants, and overall, there was a reasonable balance of gender across studies. The selected studies operationalised school-led nature interventions as including greenspace schoolyards, school gardens, and outdoor learning in greenspace (i.e., forests, woodland). The duration of the interventions also differed between studies. Table 3 summarises the study characteristics.

Various data sources were used to measure the wellbeing outcomes. Positive and negative affect were measured using the Zuckerman Inventory of Personal Reactions (ZIPERS; $n=1$), and Positive and Negative Affective Scale (PANAS; $n=3$). Stress was measured using salivary cortisol ($n=1$), and heart rate and blood pressure ($n=1$). PA was measured using accelerometers ($n=11$), pedometers ($n=2$); the Physical Activity Questionnaire for Older Children (PAQ-C; $n=1$); and the observation tools: System for Observing Play and Leisure Activity in Youth (SOPLAY; $n=2$), and Physical Activity Research and Assessment tool for Garden Observation (PARAGON; $n=1$). Social relationships/interactions were measured using the System for Observing Children's Activity and Relationships During Play (SOCARP; $n=2$) and a validated Dutch instrument measuring social functioning ($n=1$). Pro-social behaviour was measured using four items from the Perceived Social Self-Efficacy Scale ($n=2$), the pro-social subscale of the Strength and Difficulties Questionnaire (SDQ; $n=1$), and the Social Orientation Choice Card (SOCC; $n=1$).

The methodological quality of the studies was assessed using the EPHPP Quality Assessment Tool. Table 4 shows the quality ratings according to each assessment domain and the global rating. Ratings indicate 32% of studies (6/19) received a classification of strong (within 1.00–1.50 range), and 68% of studies (13/19) received a moderate rating (within 1.51–2.50 range). Thus, the majority of studies in this review were of moderate-standard. When observing the domain ratings, it was revealed that the tendency for bias occurred mostly in the Selection Bias, Study Design, Blinding, and Confounders domains. This is not unexpected given the applied nature of the research and the school context. The Data Collection and Withdrawals and Dropouts domains were either strong or had a negligible chance of bias.

Effectiveness of Nature Interventions

Mental Wellbeing

Positive Affect Four studies examined positive affect. Greenwood and Gatersleben (2016) found a significant increase in positive affect after 60 secondary-school students spent 20 min relaxing in school greenspace, particularly when with a friend compared to being alone, while 60 students who relaxed in a small indoor room had a reduction in positive affect. Similarly, Harvey et al. (2021) found that positive affect significantly increased among 443 (Study 1) and 105 (Study 2) primary and secondary school students after completing nature-related activities in the school nature grounds. However, Mason et al. (2022) did not find a significant effect of school lessons taught in the school garden (compared to indoor lessons) on positive affect among 65 primary school students. Mason et al. did however, find that positive affect increased in students with high emotional difficulties (but not students low in emotional difficulties) when they were in the school garden compared to the classroom.

Negative Affect Only one study (Mason et al., 2022) examined negative affect and a non-significant difference in children's negative affect was reported between school garden lessons and indoor lessons.

Stress Reduction/Restoration Two studies examined stress reduction/restoration. Dettweiler et al. (2017) found a significant decline in stress for 37 primary school students engaged in outdoor learning in a forest, compared to 11 students in traditional indoor classrooms, measured using salivary cortisol. In contrast, Greenwood and Gatersleben (2016) found a non-significant difference between relaxing in the school greenspace and an indoor room, on secondary-school students' stress restoration, as measured by heart rate and blood pressure levels.

Physical Wellbeing

Physical Activity (PA) Thirteen studies examined PA. Seven studies investigated the relationship between outdoor learning in nature and students' PA and five of those studies found significant positive effects. Dettweiler et al. (2017) and Romar et al. (2019) found that outdoor learning in a forest significantly increased primary school students' PA, respectively, compared to traditional indoor classes; and Peacock et al. (2021) found that PA significantly increased from pre- to post-intervention among 69 4th grade students from an outdoor education program in nature. Finn et al. (2018) also found that 44 primary school students' PA significantly increased during outdoor education in nature compared to a typical school day. Wells et al.'s (2014) Randomised Controlled Trial (RCT) reported that 115 primary school students who engaged in school lessons/activities in their school garden, compared to 112 students in the waitlist control, had a significant increase in PA from baseline to post-intervention.

Table 4 Methodological quality assessment of selected studies

Author, Year	Selection Bias	Study Design	Confounders	Blinding	Data Collection	Withdrawals and Dropouts	Global Quality
Bolling et al. (2021)	2	2	1	2	1	3	Moderate (1.83)
Dettweiler et al. (2017)	2	2	1	2	1	1	Strong (1.5)
Finn et al. (2018)	2	2	3	2	1	3	Moderate (2.17)
Greenwood and Gatersleben (2016)	3	1	1	2	1	1	Strong (1.5)
Harvey et al. (2021); Study 1	3	2	3	2	1	3	Moderate (2.33)
Harvey et al. (2021); Study 2	2	2	3	2	1	3	Moderate (2.17)
Mårtensson et al. (2014)	1	2	3	2	3	1	Moderate (2)
Mason et al. (2022)	2	2	1	2	1	1	Strong (1.5)
Pagels et al. (2014)	2	2	1	2	1	1	Strong (1.5)
Peacock et al. (2021)	2	2	1	2	1	1	Strong (1.5)
Pirchio et al. (2021); Study 1	2	2	3	2	1	3	Moderate (2.17)
Pirchio et al. (2021); Study 2	2	2	3	2	1	3	Moderate (2.17)
Raney et al. (2019)	2	3	3	2	1	3	Moderate (2.33)
Raney et al. (2021)	2	3	3	2	1	3	Moderate (2.33)
Romar et al. (2019)	3	2	1	2	1	1	Moderate (1.67)
Trapasso et al. (2018)	2	2	1	2	1	2	Moderate (1.67)
Van Dijk-Wesselius et al. (2018)	2	2	1	2	1	3	Moderate (1.83)
Wells et al. (2014)	1	1	1	2	1	3	Strong (1.5)
Wood et al. (2014)	2	1	1	2	1	3	Moderate (1.67)

Domain ratings: 1 = strong, 2 = moderate, 3 = weak

However, Bolling et al. (2021) found a non-significant difference in children's PA levels between learning in greenspace and a traditional school day; and Trapasso et al. (2018) also found non-significant results for weekly forest school lessons on 59 primary school students' total PA levels, compared to regular school lessons.

Six studies investigated the effects of greenspace schoolyards on students' PA levels and four of those studies reported significant positive results. Pagels et al. (2014) found that 2nd, 5th, and 8th grade students who attended schools with artificial grass ($n=37$) or greenspace schoolyards ($n=51$), spent significantly more time in PA than students attending schools with paved-gravel ($n=59$) or play equipment schoolyards ($n=42$). In Wood et al.'s (2014) study, 25 primary school students' PA also significantly increased when they played on the school's greenspace field compared to the playground. Raney et al. (2019) reported a significant increase in PA from pre- to post-intervention for primary school students who had a greenspace schoolyard renovation (i.e., added greenery to schoolyard; experimental school, $n=355$). Students in the control school (i.e., paved schoolyard, $n=82$) showed non-significant differences in their pre- to post-PA levels. At 16-month follow-up, students in the experimental school had significantly higher PA than students in the control school (Raney et al., 2021). In contrast, Mårtensson et al. (2014) found non-significant differences in the PA levels of primary school students who had a greenspace schoolyard ($n=70$) and those with a paved-gravel schoolyard ($n=117$); and Van Dijk-Wesselius et al. (2018) found that from baseline to follow-up 1 and 2, there were non-significant differences in PA levels between students in five primary schools who greened their schoolyards, and students in four control schools with paved schoolyards.

Social Wellbeing

Social Relationships/Interactions Three studies examined social relationships/interactions, and they all found significant positive results. Raney et al. (2019) reported that primary school students who attended the experimental school (i.e., greenspace schoolyard renovation) improved in their social interactions at 4-month follow-up compared to pre-intervention, while no significant pre- to 4-month follow-up changes were observed for students in the control school (i.e., paved schoolyard). Raney et al.'s (2021) 16-month follow-up study also found that social interactions significantly improved from pre-intervention to 16-month follow-up for students in the experimental school, while a non-significant difference was observed for control school students. Self-reported social relationships also significantly improved from baseline to follow-up 1 and 2 for primary school students who had greenspace schoolyards, compared to students who had paved schoolyards (Van Dijk-Wesselius et al., 2018).

Pro-social Behaviour Three studies examined pro-social behaviour and they all found non-significant results. Both of Pirchio et al.'s (2021) studies found non-significant pre- to post-intervention differences between the experimental (i.e., school visits to a nature reserve) and control condition (i.e., students who did not participate in the

nature program) on students' self-reported pro-social behaviour. Van Dijk-Wesselius et al.'s (2018) study measured pro-social behaviour using the pro-social subscale from the SDQ and the SOCC. The SOCC is an activity where children would receive gifts based on the amount of points they collected during a game. Besides collecting points for themselves, they could collect points for another child and the size of the gift is based on the amount of points collected. Children who chose to allocate points to another child for at least 4/6 turns were considered pro-social, while those allocating points to themselves in at least 4/6 turns were considered individualistic. Children who did not fall into these categories were labelled as ambiguous and were excluded from the analysis. Students were either in schools that had greenspace schoolyards (experimental) or paved schoolyards (control). From both measures, the researchers found a non-significant interaction between time (baseline, follow-up 1 & 2) and condition (experimental, control) for pro-social behaviour.

Influence of Age

Mental Wellbeing

Positive affect significantly increased after spending time in the school nature grounds for students aged 6–18 years (Study 1), 5–14 years (Study 2; Harvey et al., 2021), and 16–18 years (Greenwood & Gatersleben, 2016). However, lessons in the school garden did not significantly impact the positive and negative affect of 2nd–3rd grade students (Mage = 8.3 years; Mason et al., 2022). For stress reduction/restoration, school-led nature interventions significantly reduced the stress of 5th–6th grade students (Mage = 11 years; Dettweiler et al., 2017), but not for 16–18-year-olds (Greenwood & Gatersleben, 2016).

Physical Wellbeing

Findings for the influence of age on PA were mixed. The majority of studies focused on children, and only Pagels et al. (2014) assessed students in the adolescent range (8th grade; 14 years old). Outdoor education in nature significantly increased the PA levels of students in 5th–6th grade (Mage = 11 years; Dettweiler et al., 2017), 1st–6th grade (Romar et al., 2019), and students aged 9-10 years (Finn et al., 2018; Peacock et al., 2021). However, non-significant effects were also observed among students in 3rd–6th grade (Mage = 10.9 years; Bolling et al., 2021) and students aged 7-9 years (Trapasso et al., 2018). Furthermore, greenspace schoolyards increased the PA levels of students in 2nd, 5th, and 8th grade (ages 7-14 years), however, 2nd graders were more physically active than 5th and 8th graders (Pagels et al., 2014). Schoolyard greenspace also increased the PA levels of students in 1st-5th grade (Raney et al., 2019), 1st–6th grade (Raney et al., 2021), students aged 8–9 years (Wood et al., 2014), and 8–12 years (Wells et al., 2014). However, non-significant differences in PA from greenspace schoolyards were also found for 4th–6th grade students (Mårtensson et al., 2014) and students aged 7–11 years (Van Dijk-Wesselius et al., 2018).

Social Wellbeing

Greenspace schoolyards provided positive effects on social interactions for students in 1st–5th grade (Raney et al., 2019), 1st–6th grade (Raney et al., 2021), and students aged 7–11 years (Van Dijk-Wesselius et al., 2018). However, school-led nature interventions did not significantly impact the pro-social behaviour of students aged 9–11 years (Pirchio et al., 2021, Studies 1 & 2), and 7–11 years (Van Dijk-Wesselius et al., 2018).

Influence of Gender

Only nine studies examined the influence of gender in the relationship between school-led nature interventions and students' wellbeing outcomes. Four studies found that boys had higher PA levels than girls, regardless of the condition (Mårtensson et al., 2014; Pagels et al., 2014; Trapasso et al., 2018; Wood et al., 2014). When comparing experimental and control conditions for girls and boys separately, two studies found that girls exposed to nature interventions reported higher PA levels than girls in the control conditions, while no significant group differences were found for boys (i.e., the PA levels of boys in the experimental and control conditions were non-significant; Raney et al., 2019; Van Dijk-Wesselius et al., 2018). However, Bolling et al. (2021) and Peacock et al. (2021) did not find significant gender differences in the impact of outdoor education in nature on students' PA levels, nor did Raney et al. (2021) and Van Dijk-Wesselius et al. (2018) for schoolyard greening on students' PA and self-reported social wellbeing measures, respectively.

Discussion

The aims of this review were to (1) systematically evaluate the literature on the impact of school-led nature interventions on children's and adolescents' mental, physical and social wellbeing; and (2) examine whether the impact of school-led nature interventions on mental, physical and social wellbeing outcomes, differ according to age and gender. This review found that based on 19 moderate-to-strong quality studies, there is some evidence that school-led nature exposure enhances aspects of children's and adolescents' wellbeing. Most of the beneficial outcomes identified were regarding positive affect, PA, and social relationships/interactions. The included studies were of high ($n=6$) and moderate ($n=13$) standard using the EPHPP tool. The findings provide some practical implications for implementing school-led nature interventions to help relieve the academic and social pressures of school, and to improve students' physical health. First, the effectiveness of school-led nature interventions on mental, physical and social wellbeing will be discussed and compared with previous research. Then, the age and gender effects will be examined.

Mental Wellbeing

As positive and negative affect are two relatively independent dimensions (Watson et al., 1988), it is important to analyse them separately. Positive affect can be characterised by feelings of contentment, joy and enthusiasm, while negative affect can be characterised by distress, anger, sadness or nervousness (Watson et al., 1988). When examining the effectiveness of school-led nature interventions on children's and adolescents' affect, it was observed that nature exposure in schools improves primary and secondary school students' positive affect. In addition, lessons taught in the school garden improved the positive affect of children with high emotional difficulties, but not children low in emotional difficulties (Mason et al., 2022). These results suggest that while enhancing the emotional state of students in the general population, nature exposure may be particularly beneficial for children who have complex needs (e.g., emotional difficulties) that may not otherwise be met in traditional classrooms. Nature exposure has been associated with attention restoration, which may be an underlying mechanism for self-regulation (Taylor & Butts-Wilmsmeyer, 2020). Thus, by enhancing a person's attentional functioning through nature exposure, this can indirectly improve their emotion regulation, which can consequently increase their positive affect (Rowley et al., 2022). Consistent with the ART, the findings suggest that engaging in nature allows young people to feel cognitively restored, which can provide a pathway to improvements in mood. This is particularly important for students as the academic pressures of school can be emotionally and cognitively taxing (Vella-Brodrick & Gilowska, 2022). By enhancing students' positive affect through nature exposure in the school setting, this may indirectly improve on their attitude towards school and learning. Nevertheless, only one study in this review examined negative affect, and although non-significant results were reported, no firm conclusions can be drawn from this single review. As school can be emotionally demanding for some students, it is important that more research is conducted on whether school-led nature interventions reduce students' negative affect, on top of increasing their positive affect.

For stress restoration, the current findings suggest that school-led nature interventions may reduce children's, but not adolescents', stress levels. This discrepancy may be attributable to different factors. For one, it is possible that nature may not reduce heightened levels of stress among students, but it may reduce the stress levels experienced on a day-to-day basis. Greenwood and Gatersleben (2016) implemented a series of stressor tasks for their participants to complete at baseline to induce heightened stress levels. On the other hand, Dettweiler et al. (2017) conducted weekly school lessons in a forest. Another factor could be the differing stress levels experienced between children and adolescents. Dettweiler et al. examined students around 11 years-old, while Greenwood and Gatersleben examined students aged 16–18 years. The workload of students in their final years of secondary school can be highly stress-inducing (e.g., exams, college applications; Matsuoka, 2010). Moreover, education becomes increasingly difficult as children progress from primary to secondary school, which can result in adolescents experiencing greater levels of stress than children (Radwan et al., 2021). Therefore, school-led nature interventions may work to reduce the stress levels experienced by children, but it may not

be enough to relieve the highly stressful academic pressures experienced in adolescence. Nevertheless, these results partially support the SRT as nature can provide a restorative effect that reduces the physiological stress levels of children.

Physical Wellbeing

The majority of studies (n = 9; 69%) in this review that examined PA showed significant increases in PA levels among children from school-led nature exposures. This suggests that incorporating greenspace into schools can be a conducive way to improve students' PA levels. Outdoor lessons in nature can indirectly encourage students to move around more frequently compared to sitting stationary in indoor classrooms. For example, Dettweiler et al.'s (2017) school lesson in a forest included opportunities for students to be physically active by having planned walks to reach specific places in the forest. In addition, Romar et al.'s (2019) outdoor learning in a forest included activities that encouraged movement, such as free and teacher-organised play, cooperative learning tasks, and eating lunch around a campfire. Thus, it can be speculated that the activities incorporated during outdoor lessons in nature increases students' PA levels because it provides more movement opportunities than regular indoor classrooms. Due to the decline in physical fitness among children and adolescents (Fuhner et al., 2021; Masanovic et al., 2020), these findings are important as they suggest that by incorporating nature into the school curriculum, this may provide an avenue for students to improve their PA levels. In addition, greenspace schoolyards also appear to be effective at increasing children's PA. A possible explanation is that by incorporating greenspace into the schoolyard, children are provided with new opportunities to engage in non-sport activities that are often characterised by frequent bouts of PA (e.g., gymnastics, tag, hide-and-seek; Raney et al., 2019). Nonetheless, when looking at some of the studies that found non-significant results for PA from school-led nature exposure (e.g., Bolling et al., 2021; Mårtensson et al., 2014; Trapasso et al., 2018), a possible explanation for the mixed findings could be in the duration of the nature interventions. Studies showing significant positive effects had long study durations, such as interventions that ran for a whole school year (e.g., Dettweiler et al., 2017; Wells et al., 2014). In contrast, Bolling et al. had a variety of outdoor education settings, with only 10 school days in greenspace. Mårtensson et al.'s study ran for one week, and Trapasso et al.'s study had one outdoor learning day per week, for 12 weeks only. It is therefore possible that frequent and longer durations of school-led nature exposures may be more beneficial at increasing children's PA levels.

Social Wellbeing

The findings of this review showed that school-led nature interventions increase children's social relationships and interactions. These results are similar to those of Rose et al. (2018) who found that a school camp in nature improved students' peer relations. A possible explanation for the current finding is that by including

greenspace in schoolyards, there is an open space available that can provide children with opportunities to engage in activities that require cooperative and creative play, which can help to improve their social skills (e.g., cooperation, communication, negotiation; Raney et al., 2019). By engaging in group interactions, this can increase their social competence (Raney et al., 2021). Therefore, as greenspace provides open spaces for children to interact freely and creatively in play activities, this can indirectly improve on the skills required for developing social relationships. However, the studies examining pro-social behaviour found non-significant results, which are consistent with Furman and Sibthorp's (2014) findings. The current findings suggest that school-led nature interventions do not impact on students' pro-social behaviour. It is likely that because pro-social behaviour is determined by internal (e.g., moral reasoning, empathy/sympathy, personality) and external factors (e.g., family and peer influences, schooling, culture; Furman & Sibthorp, 2014), nature exposure may not be impactful enough to influence the various thought processes behind executing pro-social behaviour. Hence, while school greenspace provides open spaces that allow for children to engage in group-play, which can consequently improve on their social interactions, school greenspace may not be enough to improve on their pro-social behaviour.

Influences by Age

The results on the influence of age were mixed, which makes it difficult to identify any clear trends. For example, positive affect increased in three studies among students with ages ranging from 5 to 18-years-old. However, school-led nature exposure did not increase the positive affect of 8-year-old students in Mason et al.'s (2022) study. It may be possible that nature potentially elicits greater positive emotions among older students (i.e., adolescents) compared to younger children, however, as Harvey et al. (2021) did not differentiate between children and adolescents in their analyses, the effect of age (children vs. adolescents) still remains unclear for positive affect. When observing the influences of age on stress reduction, the results suggest that school-led nature interventions reduce the stress of children (i.e., 11-year-olds), but it may not reduce the stress of 16 to 18-year-olds. However, the exploration of the age effects for stress reduction are limited because only two studies examined this variable. The age trends for PA were very mixed, with nine studies reporting significant increases in PA for students in 1st to 8th grade, while four studies reported non-significant results for students in 3rd to 6th grade. An explanation could lie in the differences in study design and quality. Five out of the nine studies that reported significant results for PA had study designs that compared between groups over time, with one study being a RCT, while this study design was only implemented in one out of the four studies that showed non-significant results (see Table 3). Moreover, the majority of studies that reported significant positive results had stronger quality-standard than the studies reporting non-significant results (see Table 4). Therefore, it is possible that well-developed studies with robust study designs elicit greater positive findings for PA from school-led nature interventions. Interestingly, Pagels et al. (2014) found a decline in PA from 2nd graders to 5th and

8th graders. This is consistent with previous findings that PA decreases with age (Bates et al., 2018; Sherar et al., 2007). A reduction in social support for PA engagement, lower perceived athletic competency, and reduced access to organised activities as children get older, may be possible reasons for this observation (Belanger et al., 2011). The influence of age on the social wellbeing outcomes also remains unclear as the included studies only examined the childhood population. Overall, as the majority of the included studies did not perform a moderation analysis for the effects of age, no firm conclusions can be drawn at this stage regarding the influence of age in the relationship between school-led nature interventions, and children's and adolescents' wellbeing.

Influences by Gender

This review found interesting gender effects in the relationship between school-led nature interventions and students' wellbeing. The influence of gender was mainly examined in studies measuring PA. The results showed that boys had greater PA levels than girls, regardless of the condition they were in, suggesting that boys are more physically active than girls at school. Inequities in PA participation have been reported, with women being less active than men (Ball et al., 2015). This may be because women often have less PA opportunities than their male counterparts who often engage in competitive sports (Bikomeye et al., 2021). However, when comparing experimental and control conditions for girls and boys separately, girls exposed to nature interventions had greater PA levels than girls who did not. Boys did not show a significant group difference in their PA levels. These results are consistent with Bikomeye et al.'s findings that greenspace schoolyards improve the PA levels of girls more than boys, as well as findings by Dyment et al. (2009) that girls (compared to boys) are more likely to exert PA in areas that promote open-ended play (e.g., greenspace). It may be possible that as greenspace contains a variety of flora, this can promote open-ended play by providing a space for girls to use their imagination to create play activities (e.g., role-playing). Therefore, due to their play activities, it appears that asphalt areas which are ideal for running and sports favour PA among boys, while greenspaces can be more appealing for play among girls (Fjørtoft et al., 2009). Hence, by incorporating nature into schools, this may allow girls to become more physically active, which may help to reduce the PA gap observed between genders.

Limitations, Strengths, Future Directions and Implications

The current findings should be interpreted in light of some limitations. The study quality was examined using the EPHPP Quality Assessment tool and only six studies adhered strongly to quality standards. Thirteen out of the 19 studies were of moderate quality. As only six out of the 19 studies were of a strong-quality standard, this can potentially impact on the overall confidence in the conclusions drawn regarding the cause-and-effect relationship between school-led nature interventions and the

examined variables. When looking at the different domains, the study quality in this field tends to have moderately-to-poor selection bias and study design. Other areas of bias are in the confounders and blinding domains. As most of the studies were conducted in real-world settings, blinding and confounders may not always be controlled for or reported. However, the risk of bias highlights that the results should be interpreted with caution, and future research in this field should consider designing more robust study designs to increase the internal validity, so that firmer conclusions can be drawn. On the other hand, by conducting research in real-world settings, such as in schools, this enhances the ecological validity, which can be seen as a strength.

Another limitation of this paper lies in the fact that only a select number of key wellbeing variables were examined in this review, which makes it difficult to generalise the findings to mental, physical, and social wellbeing as a whole. Future research should explore other wellbeing areas (e.g., life satisfaction, BMI, social belonging) to determine the generalisability of school-led nature interventions' effectiveness on youth mental, physical and social wellbeing. It was also observed that the majority of existing research was on PA, with limited research on affect, stress reduction, social relationships and pro-social behaviour. Future studies may want to consider conducting more research regarding the effectiveness of school-led nature interventions on young people's mental and social wellbeing as these domains are equally as important as physical health.

This review also did not include non-English articles, which may explain the under-representation of studies outside of English-speaking countries. As the development of greenspace is a challenge for cities in developing countries (Kabisch et al., 2015), future research should consider including non-English papers and grey literature to obtain a more diverse understanding of the wellbeing effects. Furthermore, the majority of studies in this review did not perform a moderation analysis to examine the age effects. The studies in this review also mostly examined children, with few examining adolescents. This provided limited ability to explore the influences of age in the relationship between school-led nature interventions and wellbeing outcomes among children and adolescents, making it difficult to draw comparisons and inferences. Future studies in this field should consider performing a moderation analysis to better examine how school-led nature interventions impact different age groups. Nonetheless, a potential strength of this paper was in the inclusion of only school-led nature interventions, which may reduce factors such as family affluence and neighbourhood perceptions, from confounding the results. Although this paper exclusively looked into school-led nature interventions, it is important to note that the studies were highly diverse in terms of the methodology used and the intervention characteristics (e.g., outdoor classrooms, school garden, greenspace schoolyards). Due to this heterogeneity, a meta-analysis to aggregate the effect sizes of the included studies was not conducted for this review paper. Aggregating studies employing different designs can artificially inflate meta-analytic effect sizes and yield effect sizes that are uninterpretable unless studies are grouped according to design and then meta-analysed (Higgins & Green, 2011). Moreover, if the number of studies is small, sampling error becomes a significant issue (Schmidt & Hunter, 2015). Given the current review did include studies with different study designs (e.g., RCTs, quasi RCTs, one group cohort) and a relatively small number of studies were included in the review, a meta-analysis was

not deemed to be suitable. Therefore, the overall effect sizes of intervention effectiveness cannot be determined with this paper, however, this may be an area of research that future studies may want to explore.

Overall, to the authors' knowledge, this review is the first to investigate exclusively school-led nature interventions on children's and adolescents' mental, physical and social wellbeing outcomes. The findings can therefore inform policy makers and educators on how nature can be incorporated into the school setting to enhance students' wellbeing. For example, school designers and educators may work together to create greener schoolyards (e.g., school gardens), and school staff may consider integrating outdoor learning in nature into the school curriculum. By integrating greenspace into the school setting, this opens up opportunities for students to be exposed to environments that can improve different aspects of their wellbeing (e.g., positive affect, physical activity). This becomes important when considering the protective factor that nature exposure can have on mental health outcomes (Jimenez et al., 2021). Thus, it is highly beneficial to work towards incorporating more nature into the school setting to enhance the wellbeing of young people at school.

Conclusion

This review provides some evidence that nature exposure in the school context can improve aspects of children's and adolescents' wellbeing. Urbanisation has led to a reduction in nature exposure, particularly among children (Yin et al., 2022). This can cause adverse health consequences, such as reduced quality of life and mental health problems (Turner et al., 2004; Whiteford et al., 2013). Therefore, it is crucial to embed nature into the everyday lives of young people to benefit their wellbeing (Michaelson et al., 2020). By incorporating nature into schools, students are readily provided with opportunities to enhance aspects of their mental, physical and social wellbeing. The findings from this systematic review suggest that school-led nature interventions may potentially enhance student wellbeing. While this field of research is still emerging, the current findings provide favourable results on some key wellbeing outcomes from school-led nature interventions. This prompts the need for school designers and educators to work collaboratively to create a variety of accessible, high-quality greenspaces for young people at school.

Author Contributions Vi Ly and Dianne Vella-Brodrick were involved in the planning and conceptual ideas of the manuscript. Vi Ly performed the literature search. Vi Ly and Dianne Vella-Brodrick conducted the data analysis. The first draft of the manuscript was written by Vi Ly. The review and editing of the manuscript were conducted by Vi Ly and Dianne Vella-Brodrick. All authors read and approved the final manuscript.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions. No funding was received to assist with the preparation of this manuscript.

Declarations

Conflicts of Interests The authors have no competing interests (financial or non-financial) to declare that are relevant to the content of this article.

References

Armijo-Olivo, S., Stiles, C. R., & Cummings, G. G. (2010). Assessment of study quality for systematic reviews: A comparison of the Cochrane collaboration risk of bias tool and the effective public health practice project quality assessment tool: Methodological research. *Journal of Evaluation in Clinical Practice, 18*, 12–18. https://doi.org/10.1111/j.1365-2753.2010.01516.x

Ball, K., Carver, A., Downing, K., Jackson, M., & O'Rourke, K. (2015). Addressing the social determinants of inequities in physical activity and sedentary behaviours. *Health Promotion International, 30*(Suppl 2), ii18-19. https://doi.org/10.1093/heapro/dav022

Barrett, L. F., & Bliss-Moreau, E. (2009). Affect as a psychological primitive. *Advances in Experimental Social Psychology, 41*, 167–218.

Bates, C. R., Bohnert, A. M., & Gerstein, D. E. (2018). Green schoolyards in low-income urban neighborhoods: Natural spaces for positive youth development outcomes. *Frontiers in Psychology, 9*, 805. https://doi.org/10.3389/fpsyg.2018.00805

Becker, C., Lauterbach, G., Spengler, S., Dettweiler, U., & Mess, F. (2017). Effects of regular classes in outdoor education settings: A systematic review on students' learning, social and health dimensions. *International Journal of Environmental Research and Public Health, 14*(5), 485. https://doi.org/10.3390/ijerph14050485

Belanger, M., Casey, M., Cormier, M., Filion, A. L., Martin, G., Aubut, S., Chouinard, P., Savoie, S. P., & Beauchamp, J. (2011). Maintenance and decline of physical activity during adolescence: Insights from a qualitative study. *International Journal of Behavioral Nutrition and Physical Activity, 8*(117), 1–9. https://doi.org/10.1186/1479-5868-8-117

Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., Kaplan, S., Sherdell, L., Gotlib, I. H., & Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. *Journal of Affective Disorders, 140*(3), 300–305. https://doi.org/10.1016/j.jad.2012.03.012

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology, 25*(3), 249–259. https://doi.org/10.1016/j.jenvp.2005.07.001

Bikomeye, J. C., Balza, J., & Beyer, K. M. (2021). The impact of schoolyard greening on children's physical activity and socioemotional health: A systematic review of experimental studies. *International Journal of Environmental Research and Public Health, 18*(2), 535. https://doi.org/10.3390/ijerph18020535

Bolling, M., Mygind, E., Mygind, L., Bentsen, P., & Elsborg, P. (2021). The association between education outside the classroom and physical activity: Differences attributable to the type of space? *Children, 8*(6), 486. https://doi.org/10.3390/children8060486

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health, 10*, 456. https://doi.org/10.1186/1471-2458-10-456

Bratman, G. N., Daily, G. C., Levy, B. J., & Gross, J. J. (2015). The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning, 138*, 41–50. https://doi.org/10.1016/j.landurbplan.2015.02.005

Chojnowska, S., Ptaszyńska-Sarosiek, I., Kępka, A., Knaś, M., & Waszkiewicz, N. (2021). Salivary biomarkers of stress, anxiety and depression. *Journal of Clinical Medicine, 10*(3), 517. https://doi.org/10.3390/jcm10030517

Cox, D. T. C., Shanahan, D. F., Hudson, H. L., Plummer, K. E., Siriwardena, G. M., Fuller, R. A., Anderson, K., Hancock, S., & Gaston, K. J. (2017). Doses of neighborhood nature: The benefits for mental health of living with nature. *BioScience, 67*(2), 147–155. https://doi.org/10.1093/biosci/biw173

Deeks, J. J., Dinnes, J., D'Amico, R., Sowden, A. J., Sakarovitch, C., Song, F., Petticrew, M & Altman, D. G. (2003). Evaluating non-randomised intervention studies. *Health Technology Assessment, 7*(27), iii–x, 1–173. https://doi.org/10.3310/hta7270

Dettweiler, U., Becker, C., Auestad, B. H., Simon, P., & Kirsch, P. (2017). Stress in school. Some empirical hints on the circadian cortisol rhythm of children in outdoor and indoor classes. *International Journal Of Environmental Research And Public Health, 14*(5), 475. https://doi.org/10.3390/ijerph14050475

Dopko, R. L., Capaldi, C. A., & Zelenski, J. M. (2019). The psychological and social benefits of a nature experience for children: A preliminary investigation. *Journal of Environmental Psychology, 63*, 134–138. https://doi.org/10.1016/j.jenvp.2019.05.002

Dyment, J. E., & Bell, A. C. (2008). Grounds for movement: Green school grounds as sites for promoting physical activity. *Health Education Research, 23*(6), 952–962.

Dyment, J. E., Bell, A. C., & Lucas, A. J. (2009). The relationship between school ground design and intensity of physical activity. *Children's Geographies, 7*(3), 261–276. https://doi.org/10.1080/14733280903024423

Effective Public Healthcare Panacea Project. (2023). *Quality assessment tool for quantitative studies* (1998), 1-4. Retrieved from https://www.ephpp.ca/PDF/Quality%20Assessment%20Tool_2010_2.pdf

Finn, K. E., Yan, Z., & McInnis, K. J. (2018). Promoting physical activity and science learning in an outdoor education program. *Journal of Physical Education, Recreation & Dance, 89*(1), 35–39.

Fjørtoft, I., Kristoffersen, B., & Sageie, J. (2009). Children in schoolyards: Tracking movement patterns and physical activity in schoolyards using global positioning system and heart rate monitoring. *Landscape and Urban Planning, 93*(3–4), 210–217. https://doi.org/10.1016/j.landurbplan.2009.07.008

Fuhner, T., Kliegl, R., Arntz, F., Kriemler, S., & Granacher, U. (2021). An update on secular trends in physical fitness of children and adolescents from 1972 to 2015: A systematic review. *Sports Medicine, 51*(2), 303–320. https://doi.org/10.1007/s40279-020-01373-x

Furman, N., & Sibthorp, J. (2014). The development of prosocial behavior in adolescents. *Journal of Experiential Education, 37*(2), 160–175. https://doi.org/10.1177/1053825913489105

Godfrey, R., & Julien, M. (2005). Urbanisation and health. *Clinical Medicine, 5*(2), 137–141.

Greenwood, A., & Gatersleben, B. (2016). Let's go outside! Environmental restoration amongst adolescents and the impact of friends and phones. *Journal of Environmental Psychology, 48*, 131–139. https://doi.org/10.1016/j.jenvp.2016.09.007

Hartig, T., Korpela, K., Evans, G. W., & Gärling, T. (1997). A measure of restorative quality in environments. *Scandinavian Housing and Planning Research, 14*(4), 175–194. https://doi.org/10.1080/02815739708730435

Harvey, D., Montgomery, L., & White, R. (2021). Just how much time outdoors in nature is enough? *School Science Review, 102*(381), 27–31.

Higgins, J. P. T., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions version 5.1.0.* The Cochrane Collaboration. Available www.handbook.cochrane.org

Huynh, Q., Craig, W., Janssen, I., & Pickett, W. (2013). Exposure to public natural space as a protective factor for emotional well-being among young people in Canada. *BMC Public Health, 13*(1), 1–14.

Jabbar, M., Yusoff, M. M., & Shafie, A. (2022). Assessing the role of urban green spaces for human well-being: A systematic review. *GeoJournal, 87*, 4405–4423. https://doi.org/10.1007/s10708-021-10474-7

Jackson, N., & Waters, E. (2005). Criteria for the systematic review of health promotion and public health interventions. *Health Promotion International, 20*(4), 367–374. https://doi.org/10.1093/heapro/dai022

Jimenez, M. P., DeVille, N. V., Elliott, E. G., Schiff, J. E., Wilt, G. E., Hart, J. E., & James, P. (2021). Associations between nature exposure and health: A review of the evidence. *International Journal of Environmental Research and Public Health, 18*(9), 4790. https://doi.org/10.3390/ijerph18094790

Kabisch, N., Qureshi, S., & Haase, D. (2015). Human–environment interactions in urban green spaces — A systematic review of contemporary issues and prospects for future research. *Environmental Impact Assessment Review, 50*, 25–34. https://doi.org/10.1016/j.eiar.2014.08.007

Kaczynski, A. T., & Henderson, K. A. (2007). Environmental correlates of physical activity: A review of evidence about parks and recreation. *Leisure Sciences, 29*(4), 315–354. https://doi.org/10.1080/01490400701394865

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 15*(3), 169–182.

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge University Press.

Kellert, S. R., & Wilson, E. O. (Eds.). (1993). *The biophilia hypothesis*. Island Press.

Kelz, C., Evans, G. W., & Röderer, K. (2015). The restorative effects of redesigning the schoolyard. *Environment and Behavior, 47*(2), 119–139. https://doi.org/10.1177/0013916513510528

Lee, K. E., Williams, K. J. H., Sargent, L. D., Williams, N. S. G., & Johnson, K. A. (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. *Journal of Environmental Psychology, 42*, 182–189. https://doi.org/10.1016/j.jenvp.2015.04.003

Liu, J., & Green, R. J. (2023). The effect of exposure to nature on children's psychological well-being: A systematic review of the literature. *Urban Forestry & Urban Greening, 81*, 127846. https://doi.org/10.1016/j.ufug.2023.127846

Mann, J., Gray, T., Truong, S., Brymer, E., Passy, R., Ho, S., Sahlberg, P., Ward, K., Bentsen, P., Curry, C., & Cowper, R. (2022). Getting out of the classroom and into nature: A systematic review of nature-specific outdoor learning on school children's learning and development. *Frontiers in Public Health, 10*, 877058. https://doi.org/10.3389/fpubh.2022.877058

Mårtensson, F., Jansson, M., Johansson, M., Raustorp, A., Kylin, M., & Boldemann, C. (2014). The role of greenery for physical activity play at school grounds. *Urban Forestry & Urban Greening, 13*(1), 103–113. https://doi.org/10.1016/j.ufug.2013.10.003

Masanovic, B., Gardasevic, J., Marques, A., Peralta, M., Demetriou, Y., Sturm, D. J., & Popovic, S. (2020). Trends in physical fitness among school-aged children and adolescents: A systematic review. *Frontiers in Pediatrics, 8*, 627529. https://doi.org/10.3389/fped.2020.627529

Mason, L., Manzione, L., Ronconi, A., & Pazzaglia, F. (2022). Lessons in a green school environment and in the classroom: Effects on students' cognitive functioning and affect. *International Journal of Environmental Research and Public Health, 19*(24), 16823. https://doi.org/10.3390/ijerph192416823

Matsuoka, R. H. (2010). Student performance and high school landscapes: Examining the links. *Landscape and Urban Planning, 97*(4), 273–282. https://doi.org/10.1016/j.landurbplan.2010.06.011

McMahan, E. A., & Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: A meta-analysis. *The Journal of Positive Psychology, 10*(6), 507–519. https://doi.org/10.1080/17439760.2014.994224

Menardo, E., Brondino, M., Hall, R., & Pasini, M. (2021). Restorativeness in natural and urban environments: A meta-analysis. *Psychological Reports, 124*(2), 417–437. https://doi.org/10.1177/0033294119884063

Michaelson, V., King, N., Janssen, I., Lawal, S., & Pickett, W. (2020). Electronic screen technology use and connection to nature in Canadian adolescents: A mixed methods study. *Canadian Journal of Public Health, 111*(4), 502–514. https://doi.org/10.17269/s41997-019-00289-y

Miller, N. C., Kumar, S., Pearce, K. L., & Baldock, K. L. (2021). The outcomes of nature-based learning for primary school aged children: A systematic review of quantitative research. *Environmental Education Research, 27*(8), 1115–1140. https://doi.org/10.1080/13504622.2021.1921117

Mygind, E. (2007). A comparison between children's physical activity levels at school and learning in an outdoor environment. *Journal of Adventure Education & Outdoor Learning, 7*(2), 161–176. https://doi.org/10.1080/14729670701717580

Mygind, L., Kjeldsted, E., Hartmeyer, R., Mygind, E., Bolling, M., & Bentsen, P. (2019). Mental, physical and social health benefits of immersive nature-experience for children and adolescents: A systematic review and quality assessment of the evidence. *Health & Place, 58*, 102136. https://doi.org/10.1016/j.healthplace.2019.05.014

Pagels, P., Raustorp, A., De Leon, A. P., Mårtensson, F., Kylin, M., & Boldemann, C. (2014). A repeated measurement study investigating the impact of school outdoor environment upon physical activity across ages and seasons in Swedish second, fifth and eighth graders. *BMC Public Health, 14*(1), 1–9.

Passy, R. (2014). School gardens: Teaching and learning outside the front door. *Education 3-13, 42*(1), 23–38. https://doi.org/10.1080/03004279.2011.636371

Pawlowski, C. S., Andersen, H. B., Troelsen, J., & Schipperijn, J. (2016). Children's physical activity behavior during school recess: A pilot study using gps, accelerometer, participant observation, and go-along interview. *PLoS One, 11*(2), e0148786. https://doi.org/10.1371/journal.pone.0148786

Peacock, J., Bowling, A., Finn, K., & McInnis, K. (2021). Use of outdoor education to increase physical activity and science learning among low-income children from urban schools. *American Journal of Health Education, 52*(2), 92–100. https://doi.org/10.1080/19325037.2021.1877222

Pfattheicher, S., Nielsen, Y. A., & Thielmann, I. (2022). Prosocial behavior and altruism: A review of concepts and definitions. *Current Opinion in Psychology, 44*, 124–129. https://doi.org/10.1016/j.copsyc.2021.08.021

Pirchio, S., Passiatore, Y., Panno, A., Cipparone, M., & Carrus, G. (2021). The effects of contact with nature during outdoor environmental education on students' wellbeing, connectedness to nature and pro-sociality. *Frontiers in Psychology, 12*, 648458. https://doi.org/10.3389/fpsyg.2021.648458

Polanczyk, G. V., Salum, G. A., Sugaya, L. S., Caye, A., & Rohde, L. A. (2015). Annual research review: A meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. *Journal of Child Psychology and Psychiatry, 56*(3), 345–365. https://doi.org/10.1111/jcpp.12381

Radwan, E., Radwan, A., Radwan, W., & Pandey, D. (2021). Perceived stress among school students in distance learning during the covid-19 pandemic in the gaza strip, palestine. *Augmented Human Research, 6*(1), 1–13. https://doi.org/10.1007/s41133-021-00050-6

Raney, M. A., Bowers, A. L., & Rissberger, A. L. (2021). Recess behaviors of urban children 16 months after a green schoolyard renovation. *Journal of Physical Activity and Health, 18*(5), 563–570. https://doi.org/10.1123/jpah.2020-0280

Raney, M. A., Hendry, C. F., & Yee, S. A. (2019). Physical activity and social behaviors of urban children in green playgrounds. *American Journal of Preventive Medicine, 56*(4), 522–529. https://doi.org/10.1016/j.amepre.2018.11.004

Roberts, A., Hinds, J., & Camic, P. M. (2020). Nature activities and wellbeing in children and young people: A systematic literature review. *Journal of Adventure Education and Outdoor Learning, 20*(4), 298–318. https://doi.org/10.1080/14729679.2019.1660195

Romar, J.-E., Enqvist, I., Kulmala, J., Kallio, J., & Tammelin, T. (2019). Physical activity and sedentary behaviour during outdoor learning and traditional indoor school days among Finnish primary school students. *Journal of Adventure Education and Outdoor Learning, 19*(1), 28–42. https://doi.org/10.1080/14729679.2018.1488594

Rose, L., Williams, I. R., Olsson, C. A., & Allen, N. B. (2018). Promoting adolescent health and well-being through outdoor youth programs: Results from a multisite Australian study. *Journal of Outdoor Recreation, Education, and Leadership, 10*(1), 33–51. https://doi.org/10.18666/jorel-2018-v10-i1-8087

Rowley, M., Topciu, R., & Owens, M. (2022). A systematic review of mechanisms underpinning psychological change following nature exposure in an adolescent population. *International Journal of Environmental Research and Public Health, 19*(19), 12649. https://doi.org/10.3390/ijerph191912649

Schmidt, F. L., & Hunter, J. E. (2015). *Methods of meta-analysis: Correcting error and bias in research findings*. Sage.

Sherar, L. B., Esliger, D. W., Baxter-Jones, A. D., & Tremblay, M. S. (2007). Age and gender differences in youth physical activity: Does physical maturity matter? *Medicine & Science in Sports & Exercise, 39*(5), 830–835. https://doi.org/10.1249/mss.0b013e3180335c3c

Taylor, A. F., & Butts-Wilmsmeyer, C. (2020). Self-regulation gains in kindergarten related to frequency of green schoolyard use. *Journal of Environmental Psychology, 70*, 101440. https://doi.org/10.1016/j.jenvp.2020.101440

Taylor, L., & Hochuli, D. F. (2017). Defining greenspace: Multiple uses across multiple disciplines. *Landscape and Urban Planning, 158*, 25–38. https://doi.org/10.1016/j.landurbplan.2016.09.024

Trapasso, E., Knowles, Z., Boddy, L., Newson, L., Sayers, J., & Austin, C. (2018). Exploring gender differences within forest schools as a physical activity intervention. *Children, 5*(10), 138. https://doi.org/10.3390/children5100138

Turner, W. R., Nakamura, T., & Dinetti, M. (2004). Global urbanization and the separation of humans from nature. *BioScience, 54*(6), 585–590.

Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. F. Wohlwill (Eds.), *Human behaviour and environment: Behaviour and the natural environment* (pp. 85–125). Plenum Press.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*(3), 201–230.

van Dijk-Wesselius, J. E., Maas, J., Hovinga, D., van Vugt, M., & van den Berg, A. E. (2018). The impact of greening schoolyards on the appreciation, and physical, cognitive and social-emotional well-being of schoolchildren: A prospective intervention study. *Landscape and Urban Planning, 180*, 15–26. https://doi.org/10.1016/j.landurbplan.2018.08.003

Vanaken, G. J., & Danckaerts, M. (2018). Impact of green space exposure on children's and adolescents' mental health: A systematic review. *International Journal of Environmental Research and Public Health, 15*(12), 2668. https://doi.org/10.3390/ijerph15122668

Vella-Brodrick, D. A., & Gilowska, K. (2022). Effects of nature (greenspace) on cognitive functioning in school children and adolescents: A systematic review. *Educational Psychology Review, 34*(3), 1217–1254. https://doi.org/10.1007/s10648-022-09658-5

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063–1070.

Wells, N. M., Myers, B. M., & Henderson, C. R., Jr. (2014). School gardens and physical activity: A randomized controlled trial of low-income elementary schools. *Preventive Medicine, 69*(Suppl 1), S27-33. https://doi.org/10.1016/j.ypmed.2014.10.012

Whiteford, H. A., Degenhardt, L., Rehm, J., Baxter, A. J., Ferrari, A. J., Erskine, H. E., Charlson, F. J., Norman, R. E., Flaxman, A. D., Johns, N., Burstein, R., Murray, C. J., & Vos, T. (2013). Global burden of disease attributable to mental and substance use disorders: Findings from the Global Burden of Disease Study 2010. *Lancet, 382*(9904), 1575–1586. https://doi.org/10.1016/S0140-6736(13)61611-6

Wilson, E. O. (1984). *Biophilia*. Harvard University Press.

Wood, C., Gladwell, V., & Barton, J. (2014). A repeated measures experiment of school playing environment to increase physical activity and enhance self-esteem in UK school children. *PLoS One, 9*(9), e108701. https://doi.org/10.1371/journal.pone.0108701

Yao, W., Zhang, X., & Gong, Q. (2021). The effect of exposure to the natural environment on stress reduction: A meta-analysis. *Urban Forestry & Urban Greening, 57*, 126932. https://doi.org/10.1016/j.ufug.2020.126932

Yin, S., Kasraian, D., & van Wesemael, P. (2022). Children and urban green infrastructure in the digital age: A systematic literature review. *International Journal of Environmental Research and Public Health, 19*(10), 5906. https://doi.org/10.3390/ijerph19105906

Zhang, Y., Mavoa, S., Zhao, J., Raphael, D., & Smith, M. (2020). The association between green space and adolescents' mental well-being: A systematic review. *International Journal of Environmental Research and Public Health, 17*(18), 6640. https://doi.org/10.3390/ijerph17186640