Psycho-Physiological Stress Recovery in Outdoor Nature-Based Interventions: A Systematic Review of the Past Eight Years of Research

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Abstract: Background: In modern, urban daily life, natural environments are increasingly recognized as an important resource for stress recovery and general well-being. Aim: the present review aims to provide an overview and synthesis of the past eight years’ research into the psycho-physiological effects of outdoor nature-based interventions, related to stress recovery. Method: a structured search was performed in seven databases, returning 5618 articles. Removal of duplicates and initial screening gave a total of 95 studies. After full text reading, 36 studies were included in the assessment. Results: most of the psychological outcomes were related to different emotional measures. The synthesis of the results points towards outdoor, nature-based exposure having a positive effect on different emotional parameters, related to stress relief. The studies into physiological measures showed more equivocal results. Conclusion: the research, conducted over the past eight years, into outdoor, nature-based exposure has now attained a sound evidence base for psychological and especially emotional effects, but the evidence base for physiological effects within this timeframe shows a great degree of heterogeneity. Limitations: interpretation of the results is limited by the review only covering the past eight years’ research on the subject.

Keywords: health-promoting environments; natural environments; mood; self-estimated stress; heart rate variability; cortisol; narrative synthesis; EPHPP quality assessment

1. Introduction

According to the World Health Organization, stress has become a serious global health risk in modern, urban daily life [1]. Since over half the world’s population now lives in urban areas, it is vital to find ways of promoting stress recovery in daily life [2]. One method that is receiving increased attention is spending time in nature. Natural environments are today acknowledged as an important public health resource for promoting stress recovery and general well-being [3,4].

The research has mainly come from European and North American research institutions. However, more and more studies are being carried out in Asian countries, especially Japan and South Korea, where the concept of shinrin-yoku (‘forest bathing’), first proposed in 1982, is becoming increasingly popular and scientifically recognized [5].

Several recent reviews have been conducted on the health benefits of nature, focusing on various health-related parameters and environments [6–10]. A review by McMahan and Estes [6] included measures of negative and positive affect in a broad range of natural environments, while Haluza, Schönberger, and Cervinka focused physiological effects [7]. A review by Kondo, et al. [8]...
included all outdoor environments, not just natural environments, while James, et al. alone focused on neighborhood greenness [9]. A review by Twohig–Bennet and Jones (2018) [10] included both observational and interventional studies as well as a broad range of health-related measures. The reviews adjoin and overlap with one another even though each is unique in scope, contributing to an increasingly comprehensive understanding of the possible health effects of human–nature interactions. Overall, they find positive associations between natural environments and various aspects of human health. However, they also reach similar conclusions to the effect that the evidence base remains limited by study designs and/or high levels of heterogeneity.

The present review seeks to provide an overview of the past eight years’ research into psycho-physiological effects, related to stress recovery, of outdoor green nature exposure. The rationale for the limited time frame was mainly directed by limited resources (funding), and the specific timeframe was chosen because the last review of the psychological and physiological effects of nature exposure was published by Bowler et al. [11] in 2010. However, it should be highlighted that the present review is not a direct continuation of the review by Bowler et al., which compared the effects of natural environments with those of synthetic environments and had a boarder scope concerning health.

1.1. Psychological and Physiological Stress Recovery

Stress arousal is human beings' natural response to a strain that is appraised as potentially threatening and that gives rise to negative emotions [12]. The appraised threat starts a cascade of physiological responses to mobilize energy: steroid hormones are released in the endocrine system, and the sympathetic nervous system is activated, which affects cardiovascular functioning and increases heart rate and perspiration [13].

According to Roger Ulrich’s environmental and psycho-psychological stress recovery theory [14], stress recovery involves both physiological and physiological components. Physiological recovery entails a shift to parasympathetic nervous activity, which sustains the organism’s healthy functions in the cardiovascular, endocrine, and immune system, whereas psychological recovery entails a positive change in emotional state.

Recovery of cognitive functioning, as set forth in Steven and Rachel’s Attention Restoration Theory [15], can also be seen as related to stress recovery. However, as the latest reviews on the cognitive effects of natural environments have been published quite recently [16,17], it was decided not to include this dimension in the present review and to instead focus on psychological and physiological aspects of stress recovery.

1.2. Research Questions

What is the latest evidence base for psychological effects, related to stress recovery, by nature exposure?

What is the latest evidence base for physiological effects, related to stress recovery, by nature exposure?

2. Method

The methodology of the systematic review followed the guidelines set forth in the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) [18]. The PICO (Population/Problem, Intervention, Comparison, Outcome) framework (Table 1) was used to clarify the objectives of the review and facilitate the search strategy. (The full protocol in Danish can be acquired by contacting the corresponding author.)
Table 1. Population, intervention, comparison, and outcome variables.

| P | I | C | O |
|---|---|---|---|
| Population/Problem | Intervention | Comparison | Outcome |
| Adults (18+), all ethnicities, all countries, with or without stress-related issues/illness, without mental disabilities or other serious physical or mental illness. | Exposure to all types of outdoors natural green environments, with all types of sedentary and light exercise activities, in all time durations. From 2010–2018. | All kinds of comparisons or no comparison group. | Physiological (cardiovascular, endocrine, and immune) and psychological (mood, physiological stress, and well-being) outcomes related to stress prevention or stress treatment. |

2.1. Eligibility Criteria

We decided to include both randomized controlled trials (RCT) and non-randomized controlled trials. The rationale behind this decision was that the field largely still consists of non-randomized trials, and excluding non-RCT studies might thus result in an incomplete summary of the status. This is a common approach in reviews, although one should be aware of the greater risk of bias in the non-RCT studies [19] due to the less rigorous study design.

The language was limited to English and the research to peer-reviewed studies published between January 2010 and March 2018. These limitations were mainly directed by limited resources (funding, time, and translators). Limitations concerning language and peer-reviewed studies are common in reviews, but they subject the results to limitations and potential biases [20], which will be discussed in the limitations section.

To be eligible, the studies should have adult informants without mental disabilities or serious physical or mental illnesses not related to stress. The exposure should take place outdoors in natural green environments, whether in urban gardens and parks or in more remote and unspoiled areas such as forests, mountains, grasslands, and beaches. It was decided to include only outdoors nature-based interventions to obtain some consistency across studies on the environmental variable. Further studies comparing, for example, real nature and lab stimulation thereof have obtained heterogeneous results [21,22], which calls into question the transferability of results between the two settings. The same rationale of consistency in the environmental variable also led to the exclusion of blue environments such as the sea, lakes, and rivers. Only studies with sedentary and light physical activity were included, as vigorous physical exercise, such as running or mountain biking, have been found to have psychological and physiological effects in themselves [23].

To be eligible, the studies needed to entail psychological effect measures in terms of measuring changes in emotional states and/or physiological effect measures in terms of measuring changes in cardiovascular, endocrine, and/or immune functioning, in accordance with the stress recovery theory (SRT) [14]. Studies only using outcome measures, not validated through research, concerning their psychometric properties [24], were excluded. If a study entailed both validated and non-validated outcome measures, it was included, and only the validated measures were reported in the review.

2.2. Information Source and Search Strategy

A structured search was performed in the following seven databases: PUBMED, Web of Science, PsycInfo, SCOPUS, ASSIA, CINAHL, and Cocraine. The search took place in April 2018. The search string used OR to search for different physiological and psychological outcomes and different nature-based interventions respectively.

Outcome measures of emotional states, related to stress recovery, were operationalized into the following search terms: stress OR recovery OR health OR restorat OR well-being OR {well being} OR wellbeing OR well-being OR burnout OR fatigue OR emotion* OR affect* OR feeling* OR
mood OR relax*. Outcome measures of cardiovascular, endocrine, and/or immune functioning were operationalized into the following search terms: cardiovascular OR [blood pressure] OR heart rate OR [heart rate] OR endocrine OR immune OR physiological* OR cortisol OR noradrenaline OR adrenaline OR dopamine.

The possible outcomes were combined with possible outdoors nature-based interventions in the search string by AND.

Search terms for outdoors green nature-based interventions were natur* OR green OR outdoor OR forest OR wilderness OR wood* OR garden OR park OR horticultur* OR [open space*] OR vegetation* OR seaside OR [sea side].

When possible, depending on the individual search engine, the subject was limited to human and the areas to psychology, social sciences, nursing, arts and humanities, medicine, multidisciplinary research, and health professions.

2.3. Inclusion and Assessment

The identified articles were screened for eligibility by title and, in case of doubt, by reading the abstract. Assessment of the included studies was based on the quality assessment tool for quantitative studies developed by the Effective Public Health Practice Project (EPHPP) [25]. This instrument provides an overall methodological rating of studies as strong, moderate, or weak based on eight parameters: selection bias, study design, confounders, blinding, data collection methods, withdrawals and dropouts, intervention integrity, and analysis. The parameters are individually rated as strong, moderate, or weak. If a study has two or more weak ratings in the parameters, it is considered weak overall. Studies with only one weak rating are considered moderate, and only studies with no weak ratings are considered strong. The tool has been evaluated for construct validity and inter-rater reliability [26]. Each study was assessed independently by two researchers using the EPHPP tool. The individual assessments were discussed between the research team (authors), and a final rating was granted to each study based on agreement between researchers. In order to handle possible duplicates, it was decided that if the same study was reported in several papers, the papers would be included if they involved different effect measures related to the scope of the review. In case of duplication of results, only the results from the first-published paper would be included.

3. Results

3.1. Article Selection Process

The database search returned 5618 articles. Removal of duplicates and initial screening gave a total of 95 studies. After full-text reading, 59 studies were excluded, and 36 studies were included in the assessment and synthesis (Figure 1).

3.2. Characteristics of Included Studies

Table 2 summarizes the characteristics of the included studies: country of origin, study design, sample size and characteristics, type of intervention and control, time duration, and quality assessment.
### Table 2. Characteristics of included studies.

| Main Author, Year | Country       | Study Design | Sample Size | Characteristics | Age | Gender | Intervention               | Control               | Duration | Quality |
|-------------------|---------------|--------------|-------------|-----------------|-----|--------|-----------------------------|-----------------------|----------|---------|
| Grazuleviciene, 2016 | Lithuania     | RCT          | 10 (10)     | Coronary artery disease | 45–75 y | Mixed | Park walks                 | Urban walks           | 7 days    | Weak (II) |
| Razani, 2018       | USA           | RCT 2:1 ratio| 50 (28)     | Low-income parents | Mixed | Facilitated park tours     | No facilitated tours | 3 months | Moderate (III) |
| Niedermeyer, 2017  | Austria       | RCT crossover| 42 (42)     | Healthy individuals | M32 y | Mixed | Mountain hiking             | Treadmill/sitting     | 3 h       | Weak (II) |
| Han, 2016          | South Korea   | CCT          | 14 (14)     | Elderly with poor mental health | NA | NA | Horticultural therapy | Passive control        | 10 weeks  | Weak (II) |
| Kjellgren, 2010    | Sweden        | CCT          | 9 (9)       | Individuals suffering from stress | 37 y | Mixed | Relaxation in nature | Slideshow of nature | 30 min    | Moderate (II) |
| Mao, 2011          | China         | CCT          | 10 (10)     | University students | NA | Male | Stay/walk in forest        | Stay walk in city     | 2 days    | Weak (I) |
| Largo-Wright, 2017 | USA           | CCT          | 18 (19)     | University office staff | M49 y | Mixed | Daily outdoor break         | Daily indoor break    | 4 weeks   | Moderate (III) |
| Lee, 2010          | Japan         | CCT          | 12 (12)     | University students | M21 y | Male | Sitting in forest           | Sitting in urban park | 15 min    | Weak (I) |
| Olafsdottir, 2017  | Iceland       | CCT          | 20 (24)     | Inactive university students | NA | NA | Nature walk                 | Treadmill/nature videos | 40 min    | Weak (I) |
| Passmore, 2014     | Canada        | CCT          | 43 (41)     | Undergraduate students | NA | Mixed | Own choice nature activity | Own choice activity    | 2 weeks   | Weak (I) |
| Van den Berg, 2011 | Netherlands   | CCT          | 14 (16)     | Allotment gardeners | 38–79 y | Mixed | Gardening                   | Indoor reading         | 30 min    | Weak (II) |
| Fuegen, 2018       | USA           | CCT crossover| 181 (181)   | University students | M22 y | Mixed | Green walk/green rest       | Treadmill/rest         | 15 min    | Weak (I) |
| Gidlow, 2015       | UK            | CCT crossover| 38 (38)     | Unstressed adults | M41 y | Mixed | Green walk/blue walk        | Urban walk             | 30 min    | Weak (II) |
| Gladwell, 2016     | UK            | CCT crossover| 13 (13)     | Healthy individuals | M39 y | Mixed | Nature walk                 | Campus walk            | 30 min    | Weak (II) |
| Horiuichi, 2014    | Japan         | CCT crossover| 15 (15)     | Healthy volunteers | M36 y | Mixed | Sit and view in forest      | View a curtain         | 15 min    | Weak (I) |
| Im, 2016           | South Korea   | CCT crossover| 41 (41)     | Undergraduate students | 18–35 y | Mixed | Forest exposure              | Urban exposure         | 2 h       | Weak (I) |
| Kobayashi, 2017    | Japan         | CCT crossover| 408 (408)   | Young individuals | NA | Male | Forest viewing              | Urban viewing           | 15 min    | Weak (I) |
| Song, 2015         | Japan         | CCT crossover| 23 (23)     | University students | M22 y | Male | Park walk                   | City walk              | 15 min    | Weak (I) |
| Stigsdotter, 2017  | Denmark       | CCT crossover| 51 (51)     | University students | 20–36 y | Female | View and walk in arboratum | View and walk in city | 55 min    | Weak (II) |
| Tyrväinen, 2014    | Finland       | CCT crossover| 77 (77)     | Workers in Helsinki | 30–61 y | Mixed | View and walk in woodland    | View and walk in city  | 45 min    | Moderate (III) |
| Berman, 2012       | USA           | pre/post crossover | 20 (20) | Depressive disorder | M26 y | Mixed | Park walk                   | Urban walk             | 50 min    | Weak (I) |
| Li, 2016           | Japan         | pre/post crossover | 19 (19) | Middle-aged | 40–69 y | Male | Guided walks in forest park| Urban guided walks     | 1 day     | Weak (I) |
| Toda, 2013         | Japan         | pre/post crossover | 20 (20) | Volunteers | 64–74 y | Male | Woodland walk                | Sitting in office       | 45 min    | Weak (I) |
| Main Author, Year | Country       | Study Design          | Sample Size | Characteristics                  | Age       | Gender | Intervention                      | Control         | Duration | Quality Assment |
|------------------|---------------|-----------------------|-------------|-----------------------------------|-----------|--------|-----------------------------------|-----------------|----------|----------------|
| [50] Bang, 2017  | South Korea   | pre/post crossover    | 51 (48)     | University students               | M:26 y    | Mixed  | Forest walk in lunch break        | Passive control  | 6 weeks  | Weak (II)      |
| [51] Marselle, 2014 | UK            | pre/post 2 groups     | 15 (16)     | Adults                            | NA        | NA     | Group walks in nature             | Passive control  | 13 weeks | Moderate (III) |
| [52] Bird, 2015  | Australia     | pre/post              | 20          | Veterans                          | 31–61 y   | Male   | Outdoor therapy program           | Nature-based recreation | 6 days   | Weak (I)       |
| [53] Duvall, 2014 | USA           | pre/post              | 98          | Veterans                          | 20–49 y   | Mixed  | Forest walk in lunch break        | Passive control  | 4–7 days | Weak (II)      |
| [54] Hofmann, 2017 | Germany       | pre/post              | 85          | Volunteer gardeners               | 25–70 y   | Mixed  | Urban gardening                   | Forest walk      | 6 months | Weak (II)      |
| [55] Iwata, 2016 | Ireland       | pre/post              | 15          | Mental ill health                 | 32–72 y   | Mixed  | Forest walk                       | Walk in nature   | 13 weeks | Weak (I)       |
| [56] Marselle, 2016 | UK            | pre/post              | 933         | Elderly                           | 55–74 y   | Mixed  | Forest therapy program            | Walk in nature   | 13 weeks | Weak (I)       |
| [57] McCaffrey, 2016 | USA          | pre/post              | 195         | Adults with stress                | N/A       | Mixed  | Forest therapy program            | Garden walks     | 6 weeks   | Weak (II)      |
| [58] Ochiai, 2015a | Japan         | pre/post              | 9           | Normal-to-high blood pressure     | 40–72 y   | Male   | Forest therapy program            | Relax and walk in forest | 1 day    | Weak (I)       |
| [59] Ochiai, 2015b | Japan         | pre/post              | 17          | Middle aged                       | 40–73 y   | Female | Forest therapy program            | Forest therapy program | 2 days   | Weak (I)       |
| [60] Ohe, 2017    | Japan         | pre/post              | 43          | Office workers                    | 20–70 y   | Mixed  | Forest therapy program            | Forest therapy program | 2 days   | Weak (I)       |
| [61] Sahlin, 2015 | Sweden        | pre/post              | 57          | On sick leave due to stress       | 45 y      | Mixed  | Forest therapy program            | Nature-based therapy | 16 weeks | Moderate (III) |
| [62] Yu, 2017     | Taiwan        | pre/post              | 128         | Middle-aged and elderly           | 45–86 y   | Mixed  | Forest therapy program            | Forest bathing program | 2 h      | Weak (I)       |

* The alternative quality assessment, which excludes the blinding parameter (Table 4), is included in the Quality Assessment column with the symbols I: low; II: medium; III: strong. Abbreviations. RCT: randomised controlled trial; CCT: controlled clinical trial.
3.2.1. Study Design and Quality Assessment

Three studies were conducted as randomized controlled trials, with one being a crossover RCT. In the quality assessment, two of the studies were assessed as moderate and one was assessed as weak. Seventeen of the studies were categorized as controlled clinical trials (CCT), and nine of these had crossover designs. Five of the studies were assessed as weak, and three were assessed as moderate in quality. Sixteen studies had pre-post designs, with five including a control group and three in the form of a crossover design (Table 2). Only one of the pre-post studies was assessed as moderate in the quality assessment; the remaining fifteen studies were assessed as weak.

None of the included studies were considered strong overall according to the EPHPP quality assessment (Table 2, last column). This was due to several recurring weak ratings in the parameters: lack of information on recruitment procedure and/or using self-referred individuals as a sample (selection bias), lack of information on withdrawals and dropouts (withdrawals and dropouts), and not including comprehensive background information on the subjects (confounders). The issue of potential confounders in the EPHPP relates to relevant confounders between groups. In the studies with no control group or a crossover design, we modified the questions to concern the level of background information on the single group. Furthermore, none of the studies provided information on blinding of either assessors or informants. The parameter concerning blinding of informants to the research question might not be applicable in studies with multiple environmental exposures. However, the parameter is relevant to the blinding of the assessors. To allow for an alternative assessment of the blinding parameter issues, we carried out a second overall quality assessment excluding this parameter (Table 2, last column).

Figure 1. Flow diagram of article-selection process.
3.2.2. Location

Most of the studies were conducted in Europe (14) and Asia (14), followed by the USA (6), Canada (1), and Australia (1). A variety of European countries were represented by one study each (Denmark, Iceland, Finland, Ireland, Germany, the Netherlands, Austria, and Lithuania), two studies were from Sweden, and four studies were from the UK. In Asia, Japan was represented with nine studies, making it by far the single most-represented country in the review. South Korea, China, and Taiwan were each represented with one study (Table 2).

3.2.3. Sample Characteristics

The sample sizes varied widely, ranging from 9 to 935 subjects in the RCTs, 9 to 418 subjects in the CCTs, and 10 to 50 subjects in the pre-post studies (Table 2). Great variation was also found in sample populations, which included office workers; allotment gardeners; veterans; elderly subjects; and subjects with specific mental and physical illnesses related to stress, depression, and cardiovascular disease. The most common sample consisted of university students (10). Most studies included both sexes as subjects (22).

3.2.4. Environments and Activities

The most common research setup entailed comparing an intervention in a natural environment, forest, or park to an intervention in an urban environment, mainly in city centers (12). The most common activity was walking and/or sitting (22). A few studies involved other activities such as gardening [30,37,54] and relaxation exercises in nature [53,54,59,60]. The durations of the interventions differed substantially and were spread between 15 and 55 min (14), one to several hours (3), one to several days (8), one to several weeks (3), and months (8) (Table 2).

3.3. Summary and Synthesis of Psychological Outcomes

The heterogeneous data, wide range of interventions and study designs, generally low quality of studies (low: 31, moderate: 5, strong: 0), and recurring missing information in the results sections made the studies unsuitable for pooling for meta-analysis [63]. The findings were therefore first summarized and then compared in a narrative synthesis [64]. This was done separately for the psychological and physiological measures. An overview of the physiological measures and findings is presented in Table 3.

3.3.1. Stress, Burnout, and Recovery Outcomes

Eight studies included measures of the level of self-perceived stress (Table 3). Four studies found a significant difference between the intervention and control, in favor of the natural environment (nature > control) [31,33,42,51], with significance levels between $p < 0.05$–$0.001$. Three of the studies were CCTs. Two pre-post studies without control groups found no significant decrease from before to after the intervention [53,54]. There was an effect of condition (nature > control) in the CCT study that included a stress recovery measure [46].

3.3.2. Emotional Outcomes

In the studies including measures of positive and negative affect (Table 4), eight studies—four of them CCTs—found a positive significant difference in the pre-post measures of the intervention [36–38,46,47,51,53,56], and two studies—one RCT and one pre-post without control group—found no significant difference in the pre-post measures of the intervention [27,55].
Table 3. Overview of psychological measures and findings.

| Main Author, Year | Measure                                      | Intervention | p Value | Control  | p Value | Comparison | p Value | Effect Size | Comments                  |
|-------------------|----------------------------------------------|--------------|---------|----------|---------|------------|---------|-------------|----------------------------|
|                   | Stress, burnout, and recovery                |              |         |          |         |            |         |             |                            |
| [31] Kjellgren, 2010 | Stress and energy test                      | NA           | NA      | Difference | <0.01  | NA         |         |             |                            |
| [31] Kjellgren, 2010 | Stress VAS                                  | NA           | NA      | Difference | <0.05  | NA         |         |             |                            |
| [33] Largo-Wight, 2017 | Perceived stress scale                       | NA           | NA      | Difference | <0.05  | NA         |         |             |                            |
| [38] Razani, 2018   | Perceived stress scale                       | NA           | NA      | No difference | NA     | NA         |         |             |                            |
| [42] Im, 2016       | Stress responsive inventory                  | NA           | NA      | Difference | <0.05  | NA         |         |             | No baseline                |
| [51] Marselle, 2014 | Perceived stress scale                       | NA           | NA      | Difference | <0.001 | 0.22       |         |             |                            |
| [53] Duvall, 2014   | Perceived stress scale                       | NS           | NA      |          |         |            |         |             |                            |
| [54] Hofmann, 2017  | Stress and coping inventory                  | NS           | NA      |          |         |            |         |             |                            |
| [61] Sahlin, 2014   | Shirom-melamed burnout                       | Decrease     | NA      |          |         |            |         |             |                            |
|                   | Burnout                                      |              |         |          |         |            |         |             |                            |
| [46] Tyrväinen, 2014 | Recovery outcome scale                       | NA           | NA      | Difference | <0.01  | 0.53       |         |             |                            |
|                   | Emotions                                     |              |         |          |         |            |         |             |                            |
| [27] Grazuleviciene, 2016 | Positive and negative affect scale         | NS           | Decrease | NA      | <0.01  | NA         |         |             | Results not reported      |
| [35] Olafsdottir, 2017 | Positive and negative affect scale          | NA           | NA      |          |         |            |         |             |                            |
| [36] Passmore, 2014 | Positive and negative affect scale          | NA           | NA      | Difference | <0.05  | NA         |         |             |                            |
| [37] Van den Berg, 2011 | Positive and negative affect scale        | Increase PA  | <0.05  | NA      |         |            |         |             |                            |
| [38] Fuegen, 2018   | Positive and negative affect scale          | NA           | NA      | Difference | <0.01  | NA         |         |             |                            |
| [47] Berman, 2012   | Positive and negative affect scale          | improvement  | <0.001 | Improvement | <0.005 | NA         |         |             | Pa 0.43/Na 0.15            |
| [51] Marselle, 2014 | Positive and negative affect scale          | NA           | NA      | Difference | <0.001 | Pa 0.24/Na 0.22 |         |             |                            |
| [53] Duvall, 2014   | Positive and negative affect scale          | Improvement  | <0.05–0.001 |         |         |            |         |             |                            |
| [55] Iwata, 2016    | Positive and negative affect scale          | NS           | NA      |          |         |            |         |             |                            |
| [56] Marselle, 2016 | Positive and negative affect scale          | NA           | NA      | Difference | <0.05  | NA         |         |             |                            |
|                   | Mood                                         |              |         |          |         |            |         |             |                            |
| [32] Mao, 2011      | Profile of mood states                      | NA           | NA      | Difference | subscales | <0.05       | NA     |             | No baseline                |
| [29] Niedermeyer, 2017 | Mood survey scale                           | Improvement subscales | <0.001 | NS |         |         |             |         |             |                            |
| Main Author, Year | Measure | Intervention | p Value | Control | p Value | Comparison | p Value | Effect Size | Comments |
|------------------|---------|--------------|---------|---------|---------|------------|---------|-------------|----------|
| [34] Lee, 2010   | Profile of mood states | Improvement | <0.01 | improvement subscales | <0.01 | NA |
| [39] Gidlow, 2010 | Profile of mood states | NA | NA | NA | No difference | NA |
| [41] Horiuchi, 2014 | Profile of mood states | Improvement subscales | <0.05-0.01 | NA | <0.01 | NA |
| [44] Song, 2015 | Profile of mood states | NA | NA | NA | Difference subscales | <0.05 | NA | No baseline |
| [45] Stigsdotter, 2017 | Profile of mood states | Improvement | <0.05 | NS | NS | NA |
| [46] LJ, 2016 | Profile of mood states | NA | NA | NA | NA |
| [54] Hofmann, 2017 | Profile of mood states | NA | NA | NA | NA |
| [58] Ochiai, 2015a | Profile of mood states | Improvement subscales | <0.05 | NA | NA |
| [59] Ochiai, 2015b | Profile of mood states | Improvement subscales | <0.01 | NA | NA |

| Anxiety |
|---------|
| [29] Niedermeyer, 2017 | State trait anxiety inventory | Decrease | <0.001 | NS | NA | No baseline |
| [44] Song, 2015 | State trait anxiety inventory | NA | NA | NA | Difference | <0.01 | NA |
| [61] Sahlin, 2015 | Beck anxiety inventory | Decrease | <0.005 | NA | NA |
| [62] Yu, 2017 | State trait anxiety inventory | Decrease | <0.01 | NA | NA |

| Depression |
|------------|
| [50] Bang, 2017 | Beck depression inventory | NA | NA | NA | Difference | <0.001 | NA |
| [51] Marselle, 2014 | Major depressive Inventory | NA | NA | NA | Difference | <0.001 | 0.21 |
| [55] Iwata, 2016 | Hamilton depression rating scale | NA | NA | NA | NA |
| [55] Iwata, 2016 | Beck depression inventory | NA | NA | NA | NA |
| [61] Sahlin, 2015 | Becks depression inventory | Decrease | <0.0001 | NA | NA |

| Combined measures |
|-------------------|
| [52] Bird, 2015 | Depression, anxiety, stress scale | Decrease | <0.001 | NA | |

| Well-being, quality of life, and mental health |
|-----------------------------------------------|
| [51] Marselle, 2014 | Warwick Edinburgh mental well-being scale | NA | NA | Difference | <0.001 | 0.19 |
| [54] Hofmann, 2017 | Mental health (SF12) | NS | NS | NA |
| [56] Marselle, 2016 | Single-item happiness scale | Increase | <0.001 | NA |
| [57] McCaffrey, 2016 | Personal Growth Initiative Scale (PGIS) | Increase | <0.000 | NA |
| [57] McCaffrey, 2016 | Quality of Life Scale | Increase | <0.001 | NA |
| [61] Sahlin, 2015 | Psych. general well-being index | Increase | <0.0001 | NA |

Abbreviations. NA: not available; NS: not significant; ES: effect size (Confidence intervals: NA). Stress VAS: stress visual analogue scale; Pa: positive affect; Na: negative affect. Note: If a measurement instrument included both positive and negative dimensions, the term ‘improved’ is used if the negative has decreased and the positive increased. Only validated measurement instruments are reported in the Table.
Table 4. Overview of physiological measures and effects.

| Main Author, Year | Measure               | Intervention | Control | p Value | Comparison | p Value | Comments          |
|-------------------|-----------------------|--------------|---------|---------|------------|---------|-------------------|
| **Endocrine**     |                       |              |         |         |            |         |                   |
| Grazuleviciene, 2016 | Salivary cortisol | NS           | NS      | NS      | Difference | <0.05 |                   |
| Razani, 2018      | Serum cortisol       | NA           | NA      | NA      | Difference | <0.05 |                   |
| Han, 2016         | Salivary cortisol    | Decrease     | <0.05   | NS      |            |        |                   |
| Mao, 2011         | Hair cortisol        | NS           | NS      | NS      |            |        |                   |
| Lee, 2010         | Salivary cortisol    | NS           | NS      | NS      |            |        |                   |
| Olafsdottir, 2017 | Salivary cortisol    | NA           | NA      | No difference |           |        |                   |
| Van den Berg, 2011| Salivary cortisol    | Decrease     | <0.01   | Decrease | <0.05     |        |                   |
| Gidlow, 2015      | Salivary cortisol    | Decrease     | <0.01   | Decrease | <0.01     | No difference |        |                   |
| Kobayashi, 2017   | Salivary cortisol    | NA           | NA      | Difference | <0.001     | No baseline |        |                   |
| Toda, 2013        | Salivary cortisol    | NS           | NS      | NS      |            |        |                   |
| Ochiai, 2015a     | Serum cortisol       | Decrease     | <0.01   | NS      |            |        |                   |
| Ochiai, 2015b     | Salivary cortisol    | Decrease     | <0.05   | NS      |            |        |                   |
| **Other**         |                       |              |         |         |            |         |                   |
| Li, 2016          | Stress hormones      | Decrease     | <0.01   | Decrease | <0.01     |         |                   |
| Horiuchi, 2014    | Salivary amylases    | NA           | NA      | Difference | <0.05     |         |                   |
| **Cardiovascular**|                       |              |         |         |            |         |                   |
| Lee, 2010         | HRV                   | Improved     | p < 0.05| NA      |            |        |                   |
| Olafsdottir, 2017 | HRV                   | NA           | NA      | NA      |            |        |                   |
| Gidlow, 2017      | HRV                   | NS           | NS      | NS      |            |        |                   |
| Gladwell, 2016    | HRV                   | NA           | NA      | NA      | Difference | <0.05 |                   |
| Horiuchi, 2014    | HRV                   | Decrease HR  | <0.05   | Decrease | <0.05     | No Difference |        |                   |
| Song, 2015        | HRV                   | NA           | NA      | NA      |            |        |                   |
| Stigsdotter, 2017 | HRV                   | Increase HF  | <0.001  | Increase HF | <0.001     | No difference |        |                   |
| Bang, 2017        | HRV                   | NA           | NA      | NA      | Difference | <0.05 |                   |
| Yu, 2017          | HRV                   | NS           | NS      | NS      |            |        |                   |
### Table 4. Cont.

| Main Author, Year | Measure | Intervention | p Value | Control | p Value | Comparison | p Value | Comments |
|-------------------|---------|--------------|---------|---------|---------|------------|---------|----------|
| **Blood pressure** |         |              |         |         |         |            |         |          |
| [27] Grazuleviciene, 2016 | Blood pressure | Decrease DBP | <0.05 | NS | | | | |
| [31] Kjellgren, 2010 | Blood pressure | NA | NA | | | | | |
| [34] Lee, 2010 | Blood pressure | NS | NS | | | | | |
| [41] Huriuchi, 2014 | Blood pressure | Decrease | p < 0.05 | Decrease | p < 0.05 | No difference | | |
| [45] Stigsdotter, 2017 | Blood pressure | Decrease | p < 0.05 | Decrease | p < 0.05 | No difference | | |
| [48] Li, 2016 | Blood pressure | NS | NS | | | | | |
| [49] Toda, 2013 | Blood pressure | Decrease | <0.05 | NS | | | | |
| [58] Ochiai, 2015a | Blood pressure | Decrease | <0.05 | | | | | |
| [60] Ohe, 2017 | Blood pressure | Decrease | <0.05 | | | | | |
| [62] Yu, 2017 | Blood pressure | Decrease | <0.01 | | | | | |
| **Pulse rate** |         |              |         |         |         |            |         |          |
| [31] Kjellgren, 2010 | Pulse rate | NA | NA | | | No difference | <0.01 | |
| [34] Lee, 2010 | Pulse rate | NA | NA | | | Difference | <0.01 | |
| [48] Li, 2016 | Pulse rate | NA | NA | | | Difference | <0.01 | |
| [58] Ochiai, 2015a | Pulse rate | Decrease | <0.01 | | | | | |
| [60] Ohe, 2017 | Pulse rate | NS | NA | | | Difference | <0.05 | |
| [62] Yu, 2017 | Pulse rate | Decrease | <0.01 | | | | | |
| **Immune system** |         |              |         |         |         |            |         |          |
| [32] Mao, 2011 | Serum PI | NA | NA | | | Difference | <0.05 | |
| [32] Mao, 2011 | Oxidative stress | NA | NA | | | Difference MDA | <0.001 | |
| [42] Im, 2016 | Blood serum | NA | NA | | | Difference | <0.05–0.001 | No baseline |

Abbreviations. NA: Not available; NS: not significant; HRV: heart rate variability; HR: heart rate; HF: high frequency; PI: pro-inflammatory; MDA: malondialdehyde. Note: If a measurement instrument involves both positive and negative dimensions, the word improved is used if the negative has decreased and the positive increased. Only validated measurement instruments are reported in the table. Only main results are reported. No effect sizes were reported; therefore this column is not entailed in the Table.
Seven studies—four CCTs and three pre-post—found positive significant differences in pre-post measures of total mood disturbance or on subscales [29,32,34,45,48,58,59]. Two CCT studies found positive significant differences in both the intervention and control [34,41]. Two studies—one CCT and one pre-post—found no significant difference in the pre-post measures [39,54]. Of the three studies using anxiety measures, three found a significant decrease from the intervention [29,61,62] and one found a significant difference between intervention and control [44].

The five studies including measures of depression [50,51,55,61] were all pre-post studies. Three of the studies reported a significant decrease from the intervention (nature > control) [50,51,61], with significance levels of $p < 0.001–0.001$. One pre-post study with a combined depression, anxiety, and stress scale also found a significant decrease from the intervention [52].

### 3.4. Well-Being, Quality of Life, and Mental Health Outcomes

Five studies included measures related to well-being, quality of life, and mental health (Table 4). Four reported significant increases from the intervention [54,56,57,61], with significance levels of $p < 0.001–0.000$, and one study found no significant effect [54].

#### 3.4.1. Synthesis of Psychological Outcomes

The most studied psychological outcomes were related to different measures of emotional change (Figure 2). Eighteen studies [29,32,34,36–38,44,48,50,51,53,56,58,61,62], including one RCT and eight CCTs, found positive significant difference on different measures of emotional change (significance levels $p < 0.05–0.001$), whereas only four studies [27,39,54,55] found no significant differences in the pre-post measures. This points towards a coherent and largely unambiguous evidence base of the past eight years of nature-based interventions as having a positive effect on various emotional parameters related to stress recovery. The evidence base concerning perceived stress level measures is weaker, though mainly positive. Four of the five studies that found a significant decrease had a CCT design [31,33,42,46], which has greater weight than the three pre-post studies without control groups that did not find significant changes [53,54,61]. The lack in evidence base is therefore mostly due to the low number of studies and generally low significance levels (31,33,42: $p < 0.01–0.05$). The effects on well-being and quality of life had high significance levels in the five measures showing positive significant increase ($p < 0.001–0.000$) [54,56,57,61], and two of the studies also had large sample sizes (57: sample size 195; 56: sample size 935). However, these lacked control groups, which weakens the results. The evidence base for this aspect can therefore be regarded as promising, though lacking studies with control groups.

### 3.5. Summary and Synthesis of Physiological Outcomes

The findings are first summarized for the individual measures and then compared in a narrative synthesis [63]. An overview of the physiological measures and findings is presented in Table 4.

#### 3.5.1. Endocrine Outcomes

Ten studies, including one RCT and six CCTs, reported a significant decrease in cortisol levels and other stress hormones after the intervention [28,30,37,39,41,43,46,48,58,59] (Table 4). They all had low significance levels: $p < 0.05–0.01$. Three of the CCT studies also found a significant decrease in the pre-post measures of the control exposure [37,39,46]. Four studies found no significant difference in the pre-post measures of the intervention [27,32,34,49]. The studies that compared the effect of the intervention to that of the control also showed divergent results: three of the studies, all CCTs, found no significant difference [31,41,45], whereas three studies, two of which were CCTs, found a significant difference in favor of the intervention [40,44,50].
The use of cortisol as a measurement instrument was applied inappropriately in two of the studies [28,30], as it only was measured twice (pre-post) in interventions spanning 10 weeks [30] and three months [28], respectively. Pre-post cortisol measures are only appropriate for assessing acute responses to stress in short interventions or in interventions with long time spans to establish a pattern in cortisol levels by repeated measures several times a day over a number of days to achieve a reliable estimate [64].

3.5.2. Cardiovascular Outcomes

Nine studies used heart rate variability as a measure of cardiovascular change (Table 4). One CCT study found a significant change in the pre-post measures of the intervention [43], and three studies—one CCT and two pre-post with control groups—found a significant difference between groups in favor of the intervention [40,44,50]. Two CCT studies found positive significant differences of both intervention and control as well as no difference between groups [41,45]. Two studies found no significant differences [39,62]. An inappropriate use of the HRV (heart rate variability) measure was detected in one study [50], in which the HRV post measures were collected a week after the intervention ended (six-week intervention with lunch break walk, with non-stressed university students as subjects).

Seven studies, including one RCT, found a significant decrease in intervention pre-post measures of blood pressure [27,41,45,49,58,60,62]. However, two of these studies—CCTs—also found a significant decrease in the control group and no significant difference between groups [41,45], while three of the studies lacked a control group [58,60,62]. Two studies found no significant decrease in the pre-post measures of the intervention [34,48]. The significance levels were low in all the studies ($p < 0.05$–0.01).

The six studies that included pulse rate measures also showed divergent results: two studies without control groups found a significant decrease [58,62], whereas one study found no significant effect [60]. Two CCT studies found a difference between groups in favor of the natural environment [34,48], and one CCT study found no difference between groups [31]. The significance level for the effect was low in all the studies ($p < 0.01$).
3.5.3. Immune Outcomes

Two CCT studies included measures of immune functioning [32,42]. They found a difference in all measures in favor of the natural environment. None of the studies reported the effect of the intervention itself, and one study did not obtain baseline measures [42].

3.5.4. Synthesis of Physiological Outcomes

The studies of endocrine and cardiovascular measures show highly heterogeneous results: the numbers of studies showing a significant decrease in pre-post measures and studies reporting no significant difference in pre-post measures and/or no significant differences between intervention and control groups were almost equal (Figure 3). Studies without control groups [58–60,62] were heavily represented in the measures showing significant decreases. As several of the CCT studies found significant decreases in pre-post measures of both the intervention and control and/or no significant difference between them [31,35,37,39,41,46], the results of the pre-post studies without control groups must be questioned in terms of whether or not the positive effect was caused by exposure to the natural environment. The positive results on immune functions stem from only two studies [32,42], one of which lacked baseline measures [42]. It is therefore impossible to draw any conclusions based on this outcome measure.

![Figure 3. Synthesis of physiological outcomes of nature-based interventions.](image)

**Figure 3.** Synthesis of physiological outcomes of nature-based interventions. ■ Number of studies with positive significant difference in pre-post measures of the nature intervention alone and/or effect of condition favoring the nature intervention. □ Number of studies with no significant difference found in pre-post measures of the nature intervention. □ Number of studies with positive significant difference in pre-post measures of both intervention and control and/or no significant difference between intervention and control. Note: Some of the studies have several different measurement instruments and are thus represented in multiple columns in the figure.

4. Discussion

4.1. Quality of the Studies

The included studies were comprised of study designs using self-referred individuals (24), many of whom were university students (10), as well as pre-post designs without randomization (15). Only three of the included studies were categorized as randomized controlled trials [27–29]. Information on several methodological aspects was generally missing in the studies. The past eight years’ research into the subject must therefore be considered quite methodologically weak overall. This conclusion on the general weakness in methodology is similar to that reached in other recent reviews with slightly different scopes [6–11], namely, that more studies using rigorous and transparent methodologies and
study designs are needed. Only two studies reported effect sizes. This can be seen as a fundamental weakness in both the included studies and the review, relying solely on p values to evaluate the findings. As p values can only give information on the statistical significance of the found effect, related to the null hypotheses, and not the importance (how strong the effect is), they cannot be used to determine the therapeutic relevance of the given intervention [65]. However, one should also be aware of the potential biases when using effect sizes to perform meta-analyses on the strength of the effect across studies. It is therefore not recommended in reviews with studies assessed as weak and/or with clinical and methodological heterogeneity [63], which is the case for the present review as well as for most previous reviews.

4.2. Findings and Evidence Base

Based on the homogeneous, substantial, and statistically significant findings concerning emotional change, the evidence base for outdoor natural environments promoting this aspect of stress recovery seems sound. However, the limitation of being unable to determine the size of the effect and related therapeutic relevance as well as the assessment of the studies as generally weak should be taken into account. The evidence concerning the effects of exposure to nature on lowering self-perceived levels of stress is largely positive yet weak in the sense that there is a low number of studies and that the findings have low significance levels. The same applies to the evidence on various aspects of well-being and quality of life, which showed positive results but involved few studies, which themselves lacked control groups even though they had large sample sizes and high significance levels. Only one study measured recovery directly [46]. It showed a significant decrease and reported a large effect size. This could thus be an interesting measure, worthy of future research, especially given that the field seems saturated with measures of emotional change.

The evidence of the physiological effects related to stress recovery of the included past eight years’ nature-based interventions is more equivocal. The synthesis showed very heterogeneous results with regard to the effect on both endocrine and cardiovascular measures and very few measures of immune functioning. Due to the findings in studies with control groups (showing effect for both the intervention and control and/or no difference), it is recommended not to conduct studies with physiological measures without control groups. There are many possible explanations as to why positive outcomes were also found in control groups. One could be that the control condition was also effective or that the measurement instruments were insufficiently sensitive to detect differences. Of course, it could also simply be related to measurement errors or inappropriate use of the measurements, as was seen in two studies using cortisol measures only twice in interventions with long time duration [28,30] and one study using HRV as a post measure, a week after the intervention stopped [50].

The question remains why the physiological measures showed highly heterogeneous results. One explanation could be that the measures were insufficiently sensitive to capture the physiological effect of environmental exposure. Maybe there is a need to induce a stressor to detect significant physiological differences: a review of attention recovery found greater effect sizes when participants were induced with cognitively demanding tasks prior to exposure [17]. Another possibility is to raise the scientific level in the use of the physiological measures to achieve valid results. For example, take cortisol measures several times a day over the course of several days in interventions over a longer time span [64].

In addition, the relationship between psychological and physiological measures requires further study as the results are ambiguous. Studies using both measures find divergent results on psychological and physiological effects related to stress recovery.

4.3. EPHPP as Quality Assessment Tool

In the present review, the EPHPP tool was chosen as it is a validated and widely used assessment tool in health research [26] and has been used in previous reviews in the field [11,16]. In the EPHPP, the assessment of quality is based on eight parameters. However, it also includes questions on units of
allocation and units of analysis as well as intervention integrity, which concerns whether there is a risk of having received an unintended intervention. These questions are not part of the quality rating. However, these aspects could cause potential bias as all studies used the individual as a unit of analysis, even though a substantial number had groups as the unit of allocation. Furthermore, the studies that had long time spans with short, repeated nature exposures had a high risk of the informants receiving an unintended intervention by factors outside the nature exposure. It is therefore recommended to use more comprehensive assessment tools to assess risk of bias in future studies, for example, the Cochrane tool for RCT studies [66] and the ROBINS-I tool for non-randomized studies [67].

4.4. “Nature-Positive” Bias

The field is dominated by the use of self-referred subjects, who might be expected to have an interest in nature and natural environments. This could therefore have caused a potential “nature-positive” bias. Haga, Halin, Holmgren, and Sörqvist [68] have scientifically demonstrated the “nature-positive” bias in psychological recovery in a study in which participants heard the same soundtrack while performing a cognitively demanding task. One group was told it was the sound of a waterfall, while the other was told that it was from an industrial building site. The findings showed that the “waterfall group” reported significantly more recovery than did the “building site group”. As the setup in most studies in the review is built-up environments versus nature using self-referred individuals, there is strong cause for suspecting that the results are subject to “nature-positive” bias.

4.5. Limitations

This review has several limitations, one concerns only including published peer-reviewed research, which one could assume favors studies with significant findings and positive effects (publication bias) [69]. The large heterogeneity and non-significant results in the reported outcomes of the physiological measures in particular, however, do not support the idea that only nature-positive studies are prone to be published. However, this is a possible limitation of the study that one must take into account. On the other hand, including non peer-reviewed studies raises other potential biases, as the peer review process can be seen as a scrutiny filter for the scientific quality [70].

Another limitation concerns the inclusion of both randomized and non-randomized studies. This is a common approach in reviews, but it presents challenges when comparing studies, and it raises the risk of bias in the non-randomized studies [19]. In addition, the limitation concerning only English language studies being included raises a limitation by possibly missing out on important studies published in other languages [20].

The greatest limitation concerns the timeframe of the review. It should be seen as a limited perspective, only covering the past eight years’ research, and it raises the potential bias of studies with important contributions being published before this timeframe.

5. Conclusions

The past eight years’ research into psycho-physiological stress recovery in outdoors nature exposure supports the evidence of psychological effects, especially concerning emotional change. More ambiguous results were found regarding physiological effects. Therefore, the evidence base for the physiological effects of nature exposure in relation to the past eight years’ research must be regarded as quite weak. The general use of self-referred individuals imposes a potential strong bias. The results of the review should be seen in relation to its limitation concerning the relatively short timeframe.

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