Degree project

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Nature´s Effect on Stress in Women: A Systematic Review

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Abstract

This systematic review aims to evaluate which effects nature exposure has on stress in women and get a more objective viewpoint using measurements of physiological markers of stress to complement the many studies using subjective questionnaires. A search was done on Scopus, Medline EBSCO, and Web of Science for peer-reviewed, published, and original research. Five studies met the inclusion criteria and were included in this review. The outcome measurements included were activity in the autonomic nervous system (ANS) measured with heart-rate variability (HRV) and cerebral activity measured by near-infrared spectroscopy (NIRS). With the definition of Shinrin-Yoku in mind, nature exposure was walking in or watching the natural environment, compared to walking in or watching an urban environment. In this systematic review, four of five studies found significant results that nature exposure alleviated stress in women compared to an urban environment. These findings contribute to a growing body of evidence suggesting that nature is valuable in reducing stress-related illnesses in women. On the individual level, these findings show that nature exposure can be used as an evidence-based intervention to reduce stress in women. Furthermore, these findings clarify the benefits of including elements from nature in urban environments on a societal level.

Keywords: Nature, forest environment, stress, heart-rate variability, near-infrared spectroscopy

Nature´s Effect on Stress in Women: A Systematic Review

Imagine the scent of a sun-kissed pine tree in the summer, the wind blowing in the treetops making the sunlight flicker on the ground, and the sound of birds talking to each other in the morning hour. Breath in the clean, fresh air and drop your shoulders. Why does nature give so many of us a sense of calm and restore our energy? According to biophilia (Wilson, 1984), later termed the biophilia hypothesis (Kellert & Wilson, 1993), humans have lived on savannas for most of our evolution and therefore have a biological need to connect with nature. Nature once helped us survive, which is why we feel comfortable there, so nature is part of humans' evolutionary heritage (Gullone, 2000; Kellert & Wilson, 1993; Ulrich, 1993). For a considerably longer duration, the evolutionary adaptation of the brain took place in savannah-like environments. Even though the brain still adapts, it is more adapted to nature compared to today's urban environment (Kellert & Wilson, 1993). During 99% of human history, people have been hunter-gatherers. Thus, from an evolutionary perspective, biophilic responses and landscape preferences may differ between biological factors such as gender, age, and the presence of others. With gender differences regarding livelihood and reproduction, men and women should evaluate and use the environment differently. Not everyone will react equally to a specific environment because of a variance in vulnerability to environmental threats and predation in the past (Kellert & Wilson, 1993).

Two theories focus on the relationship between the natural environment and mental health: stress reduction theory (Ulrich et al., 1991) and attention restoration theory (Kaplan, 1995). According to Roberts et al. (2019) stress reduction theory proposes that the presence of nature gives an evolutionary response of survival and safety, a response that generates positive emotions. Attention restoration theory proposes that humans have a "soft fascination" for the natural environment (Kaplan, 1995). This fascination allows people to pay attention effortlessly to nature. Taking in the surroundings of nature without the distractions of the urban environment provides precisely the amount of stimuli humans are developed to handle (Dolling et al., 2017). Together, these theories indicate that people are physiologically and psychologically less stressed when spending time in the types of nature that have been important for our evolutionary history.

The growing separation between humans and nature has consequences for human well-being (Hodson & Sander, 2017). Many things that follow urbanization are perceived as dangerous to humans, often without consciously knowing it. Everyday things like overcrowding, background sound, sudden loud noises, air pollution, and reckless drivers are perceived as dangerous to our survival (Shuda et al., 2020). The growing urbanization makes people more exposed to these stressors of the urban environment, which influence their stress levels (Gruebner et al., 2017; Yao et al., 2021). An example of stressors in the urban environment is that people need to constantly make quick decisions to move around in a highly mobile and dense society. In addition, high-tech solutions demand our attention (Dolling et al., 2017). A widespread and everyday phenomenon such as urban light exposure can affect the circadian rhythm, changing people's sleeping patterns, which alone can affect their mental health (Gruebner et al., 2017). Thus, people who live in cities generally have a higher risk for stress-related illnesses.

According to Gallup (2021) the feeling of experiencing high-stress levels worldwide reached a record-high 40% in 2020. In 2019 that number was 35%. To get a clearer picture: 190 million more people worldwide experienced high-stress levels in just a year. The range in reported stress from country to country was 13 to 66%, so not everyone felt stress to the same degree. The incline began ten years ago, so therefore this development is not all due to the pandemic (Gallup, 2021). According to Folkhälsomyndigheten (2022), 14% of the population in Sweden between the age of 16-84 stated in 2020 that they feel stressed. When divided into gender, 18% were women, and 11% were men. In other words, more women compared to men felt stressed, and during 2006-2020, there was a slight increase in the population that was stressed, and the increase in stress was highest in ages between 16–44. Stress-related illnesses are increasing and have been since 1990. In the first quarter of 2020, mental illness accounted for 41.3% of all ongoing illnesses. Women are more often on sick leave in contrast to men, and more so due to mental illnesses. In general, women have a 25% higher risk of getting ill, 31% for a mental illness, and for stress-related mental illness, that number is 41% (Försäkringskassan, 2022).

For decades the default model for a human subject in research was a 70kg male, and this model has provided ambiguous evidence about biology and health (Clayton, 2016). One such example is the higher mortality rates for women with coronary heart disease due to the deficient identification of symptoms for women (Dijkstra et al., 2008). Understanding scientific findings in the framework of gender, differences, and similarities is essential for applying research-based interventions that work for men and women (Clayton, 2016). Considering this background within research and the fact that stress is a considerable larger problem for women compared to men, it is of utmost importance to implement research in this area on women.

Stress

The human body always strives for balance (homeostasis) and is designed with a complicated range of metabolic systems to maintain normal balance (Thomas & Lena, 2010). One definition of stress is that it is a response to a threatened balance of the body, which is counteracted by a stress response that intends to re-establish the balance (Selye, 1956; Thomas & Lena, 2010). Another definition is that stress is a maladaptive state caused by an over-activated sympathetic nervous system (Campkin, 2000). Stress is the body's way of reacting to a perceived environmental demand that can be valued as either threatening or benign and is hard to avoid in everyday life (McEwen & Gianaros, 2010; Ridner, 2004; Thomas & Lena, 2010). One stress response is the fight-and-flight response that has been crucial for human survival. Fight-and-flight is designed to trigger body arousal seconds after exposure to a stressor to stimulate a rapid reaction to get away safely (Klein & Corwin, 2002). Although the fight-and-flight response is considered the traditional reaction for both men and women to some stressors, women more often react with another response; tend-and-befriend. Building and sustaining social relationships, tending and befriending promote safety, reduce distress, and keeps the woman and potential offspring safe (Klein & Corwin, 2002).

Although the word stress is often negatively used, the underlying physiological mechanism has been crucial to human survival throughout evolution. In the right amount, stress can improve productivity (e.g., help us in a sudden threatening situation or help students prepare for an exam) and, therefore, increase individual development. In contrast, too much stress without breaks for restoration can be detrimental and cause chronic fatigue and other psychological and physiological symptoms (Dolling et al., 2017; Hanoch & Vitouch, 2004). Stress-related illnesses increase, and people have less energy (Dolling et al., 2017). According to Mulhall (1996), people must learn to either cope or be distressed with the constraining forces of stress. According to Dolling et al. (2017) there are several symptoms of stress (e.g., insomnia, increased heart rate, reductions in memory capacity, muscular aches, and headaches) and stress-related physical symptoms (e.g., anxiety, nervousness, constant fatigue, and severe pain in the neck and shoulders): symptoms that alone can affect people's work- or social life. Furthermore, if the stress develops into fatigue syndrome, it takes a long time to recover, and after recovery, people generally stay more sensitive to stress.

The leading cause of stress among youth is school, life changes, relationship problems, and wondering what career to pursue (Bhargava & Trivedi, 2018). For the adult population, issues like family demands, work deadlines, job insecurity, or a long commute may cause stress, among other things (Michie, 2002). Unpredictable and uncertain situations, or situations involving conflicts or when life changes, are situations more likely to cause stress (Michie, 2002; Mulhall, 1996). Although many sources may cause stress, this review mainly focuses on increasing urbanization and how the natural environment can affect stress.

The Stress Response

There are two major divisions within the human nervous system: the central and the peripheral (Seo et al., 2010). The autonomic nervous system (ANS), part of the peripheral nervous system, is associated with stress, among other negative states. ANS regulates the automatic bodily functions associated with heart rate, digestion, breathing, and hormonal systems (Seo et al., 2010). The sympathetic nervous system that initiates the stress response and the parasympathetic nervous system that initiates the relaxation response are both parts of ANS (Seo et al., 2010; Thomas & Lena, 2010). Thus, these two systems work together to keep the body in homeostasis. When people are exposed to chronic stress, this balance can be disturbed and cause stress-related health issues (Gazzaniga et al., 2013; Seo et al., 2010).

A whole cascade of events happens when the brain detects a threat to human homeostasis intended to increase the probability of survival (Dijkstra et al., 2008; Seo et al., 2010; Thomas & Lena, 2010). There can be either a psychological or physical stressor threatening the body's balance, making the brain initiate a stress response, and a series of chemical reactions follow. The stress response involves the release of hormones (e.g., norepinephrine and cortisol) and activation of the regulatory centers of the central nervous system (amygdala, hippocampus, and prefrontal cortex). The amygdala and hippocampus process experiences together with the brainstem, hypothalamus, and prefrontal cortex (PFC). Moreover, whether an event is interpreted as stressful or not is based on present or past experiences (McEwen & Gianaros, 2010). The amygdala, located in the medial anterior temporal lobes, processes and activates emotions and behavior. The hippocampus, located in the medial temporal lobe, determines the event's context and processes declarative and episodic memory about the event (McEwen & Gianaros, 2010). If an event is interpreted as stressful, these areas excite the hypothalamic-pituitary-adrenal (HPA) axis and ANS (McEwen & Gianaros, 2010; Mello et al., 2003; Seo et al., 2010; Thomas & Lena, 2010). The amygdala acts excitatory, and the hippocampus is in general inhibitory, although some areas act excitatory. Medial PFC, located in the anterior frontal lobes, is involved in different higher cognitive functions, one being the top-down regulation of stress. This regulation is mediated by subcortical areas (amygdala, hippocampus, and hypothalamus), and numerous prefrontal areas send direct projections to areas concerning the regulation of the stress response (McEwen & Gianaros, 2010). The HPA axis interacts closely with the locus coeruleus-norepinephrine system activating the fight-and-flight response. These systems are involved in a substantial reciprocal innervation throughout the central nervous system to turn the stress-response on and off (Dijkstra et al., 2008; McEwen & Gianaros, 2010; Mello et al., 2003). This neural circuitry can be adaptive in the short term but maladaptive in the long term (McEwen & Gianaros, 2010).

Methods to Measure Stress

Since stress depends on complex networks, measuring stress by a single marker is impossible (Yao et al., 2021). Studies have used physiological parameters such as blood pressure, pulse rate, heart rate variability (HRV), and salivary cortisol (Bedini et al., 2017; Hjortskov et al., 2004; Largo-Wight et al., 2016). These physiological markers are indicatives of central-autonomic activity or indicators of change in the immune and endocrine systems (Seo et al., 2010). In addition, electroencephalogram (EEG) and near-infrared spectroscopy (NIRS) are used to measure brain activity related to stress (Choi et al., 2015; Nagasawa et al., 2020). Several studies have used subjective questionnaires to measure the psychological aspects of stress (Balconi et al., 2019; Crivelli et al., 2019; Largo-Wight et al., 2016; Takayama et al., 2019). This review will focus on methods that measure physiological markers, such as EEG, NIRS, HRV, and salivary cortisol.

EEG measures the brain's electrical activity at the top of the scalp. The electrical activity is measured by different bands of frequency, called waves. From high to low, these bands are called: Delta, Alpha, Beta, and Gamma (Choi et al., 2015). The bands indicate different functions of the brain and nervous system activity. High-beta waves in the temporal lobe indicate a stress reaction, and alpha waves in the frontal lobe indicate a relaxed state (Choi et al., 2015; Seo et al., 2010; Ulrich, 1981). Hence, this method can be indicative of stress reactions.

NIRS is a method that measures brain activation by monitoring brain oxygenation (Tsunetsugu & Miyazaki, 2005). NIRS is non-invasive, and the portable device makes it suitable for field experiments (Tsunetsugu & Miyazaki, 2005). A decrease in brain oxygenation in the prefrontal cortex indicates that cerebral activity has attenuated, indicating a relaxed state (Park et al., 2007).

HRV is a measure of heart rate on a beat-to-beat basis, and the time interval can have a variation of 10-30%, although the heart rate per minute remains constant (Kobayashi et al., 1999). R-wave, the most prominent waveform of the electrocardiogram, is counted in numbers: a parameter known as the R-R interval variation. The power spectrum of the HRV signal is divided into frequency sections. A high-frequency component (HF, 0.15Hz-0.4Hz) represents parasympathetic nerve activity related to relaxation. On the contrary, a low-frequency component (LF, 0.04Hz-0.15Hz) represents sympathetic and parasympathetic nerve activity, and the proportion of LF/(HF+LF) represents activity in the sympathetic nervous system related to stress (Lim et al., 2021). HRV contributes to knowledge about stress levels based on the autonomic nerve reactions and the underlying processes mediating beat-to-beat changes (Kobayashi et al., 1999; Lim et al., 2021; Porges, 2007).

Cortisol is “a non-invasive indirect window on the brain” (Clow & Smyth, 2020, p. 2). The concentration of cortisol circulating through the body changes from hour to hour, and everyday emotions and thoughts can cause fluctuations in cortisol concentration. Adverse events such as stress cause a spike in cortisol, while more enjoyable events cause a reduction (Clow & Smyth, 2020). The differences in cortisol levels can be measured accurately by measurements in the saliva (Clow & Smyth, 2020).

Nature as an Intervention

Shinrin-Yoku, also called forest bathing, is when one walks in a forest environment, breathing in its air and watching it closely. In Japan, Shinrin-Yoku is a traditional practice thought of as meditation or an artform (Antonelli et al., 2019; Park et al., 2010). A relatively recent systematic review (Kondo et al., 2018) found evidence that spending time outdoors in a preferably green environment may reduce the experience of stress. Other reviews indicate that Shinrin-Yoku is useful as an intervention to reduce stress (Hansen et al., 2017; Oh et al., 2017). The interest in Shinrin-Yoku in science originates from Japan but has spread to other parts of the world (e.g., China, South Korea, Germany, Iceland, Finland, and Spain; Antonelli et al., 2019).

World Health Organization (2022) recommends self-care interventions as a critical path for every country to promote health and serve the vulnerable. Self-care interventions are quality tools that are evidence-based and support individuals in managing their health care without help from a healthcare worker (World Health Organization, 2022).

The Aim

This systematic review aims to investigate if there is evidence that nature affects stress in women. By focusing on studies that measure participants' physiological responses while spending time in nature, this thesis aims to get a more objective viewpoint of the field as a complement to the many studies using subjective questionnaires. This review aimed to include all four measurements (EEG, NIRS, HRV, and salivary cortisol). However, no studies fulfilling the inclusion criteria used EEG or salivary cortisol. Hence, even though these measurements are valuable in this field of research, this review could not include them. With the definition of Shinrin-Yoku in mind and World Health Organizations recommendation for self-care interventions, studies where participants walk, or take in the natural environment on their own, without the help of a guide or a therapist, will be included. Like in other disciplines, many studies are done with all-male participants (Kobayashi et al., 2018, 2019; Lee et al., 2011; Mao et al., 2012). According to the biophilia hypothesis, there may be gender differences in the way women and men respond to the natural environment (Kellert & Wilson, 1993). Moreover, the all-male studies can provide ambiguous evidence on interventions aimed at women (Clayton, 2016). With the increase of stress in women, it is essential to find evidence-based interventions suited for them. Given the tend-and-befriend response to stress, walking alone in nature might not work the same way for women as for men. Therefore, this review will focus on all-female studies to gather evidence for future self-care interventions in nature for women experiencing stress. By focusing on all-female studies, this review will also balance the research area regarding gender. Stress is a growing problem, as seen in the increasing number of people taking sick leave due to stress-related issues. Finding affordable (nature is free) and evidence-based, easy-to-use interventions for people to pursue on their own is crucial to relieving stress and decreasing stress-related illnesses in our society.

Methods

Search Strategy

Regarding getting an overview of the subject, the initial search consisted of different combinations of keywords (e.g., forest bathing, shinrin-yoku, forest therapy, natural environment, forest exposure, forest walking and EEG, HRV, heart rate variability, cortisol). After a closer look at several studies for more keywords and by reading about the different measures used in stress-related research combined with nature, the final search string used was ("forest environment" OR "restorative environment" OR "shinrin-yoku" OR "shinrin yoku" OR "forest therapy" OR "forest bathing" OR "therapeutic effect of forest" OR "forest environment" OR "forest landscape" OR "forest walking" OR "forest exposure") AND (nirs OR "near-infrared spectroscopy" OR "near infrared spectroscopy" OR hrv OR "heart rate variability" OR cortisol OR "salivary cortisol" OR "salivary cortisol concentration" OR eeg). The search was set on title, abstract, and keywords for Scopus, and the quotation marks were changed into curly brackets as informed by the library at the University of Skövde. There were no restrictions set for Medline EBSCO or Web of Science, and the original search string as seen above was used. The end date for the search was the 10th of March, 2022. The search gave 285 articles on three different databases (Medline EBSCO n=50, Scopus n=93, Web of Science n=142). The records of the articles were extracted, saved, and imported to Rayyan (Ouzzani et al., 2016). First, 115 duplicates were removed. The remaining 170 articles were screened by the title and abstract, and 136 additional studies were excluded due to not meeting the inclusion criteria (see inclusion and exclusion criteria). The final step was to screen the full text of the remaining 34 articles. The final screening excluded 29 articles due to different population (n = 19), wrong study design (n = 6), foreign language (n = 2), wrong outcome (n = 1), and no access (n = 1). The total sum of 5 studies was included in this systematic review (see Figure 1).

Inclusion & Exclusion Criteria

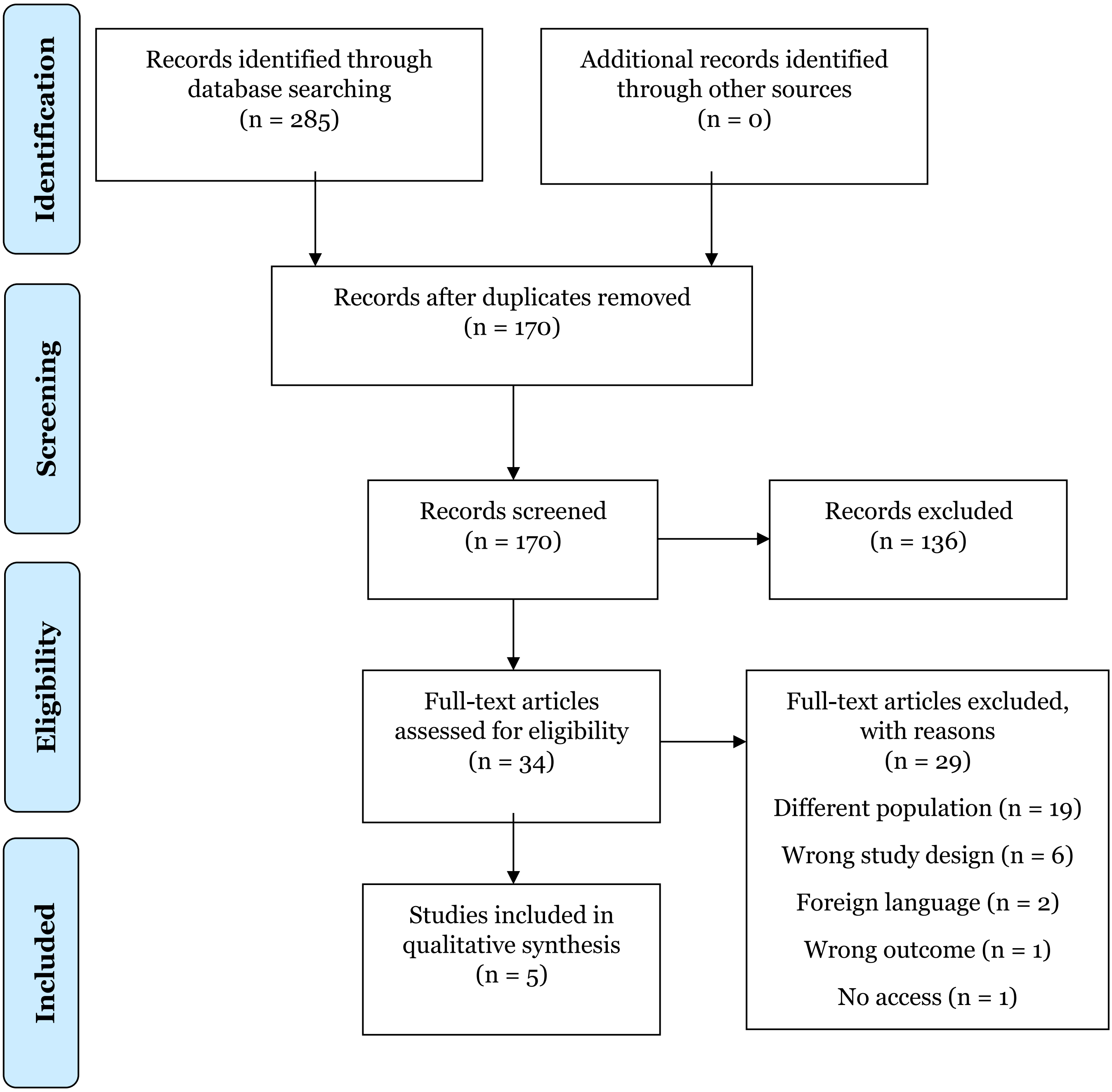
The inclusion criteria for the participants are only adult (18+) female subjects within all ethnicities and from all countries. Hence, all-male, mixed, and animal studies are excluded. Participants can be with or without stress-related issues/illnesses. The inclusion criteria for the intervention are studies with a nature-based intervention (e.g., forest bathing, forest walk, or watching a natural environment) without any additional intervention or help from a guide/therapist. Light exercise, like walking, in all time durations is allowed. Consequently, studies with exercise programs, a joining therapist or guide, pictures of nature, or virtual reality are excluded. The primary goal is to find studies that measure the physiological outcome related to stress with the neuroimaging method of near-infrared spectroscopy (NIRS) or electroencephalogram (EEG), but indirect methods of salivary cortisol and HRV will also be included. Papers must be in English, peer-reviewed, published, and be original research. Only studies available through the university database or open access are included.

Data Extraction

The data extracted and presented from the included articles are as follows (eight categories): the first author with the publication date, study design, and location, sample size, age and study population, intervention, duration of intervention, control group, outcome measurement, and results (see Table 1). Outcome measurements extracted are cerebral activity measured by NIRS and activity in the autonomic nervous system measured with HRV.

Figure 1

PRISMA 2009 Flow Diagram



Note: The literature search process, illustrated in a PRISMA 2009 Flow Diagram. Adapted from Moher et al. (2009).

Results

This review identified five papers that met the inclusion criteria (see Table 1). Although this review aimed to find and include studies using one or more of the following methods: EEG, NIRS, HRV, or salivary cortisol, there were only studies using the methods HRV and NIRS that fulfilled the inclusion criteria.

Study Characteristics

Across the five studies, there were 272 participants in total, and the data analysis are based on the measurements from 214 participants. Sample sizes ranged from 17–72, with a mean age of 21–46.1 in four studies. In the fifth study, the age ranged between 20–36 (see Table 1). The study population ranged from young female university students to adult females living in urban areas, healthy and free of psychological or physical disorders. Four of the five studies (Igarashi et al., 2015; Song et al., 2019a, 2019b, 2020) were conducted in Japan, and one study (Stigsdotter et al., 2017) was conducted in Denmark. All studies used a cross-over/within-subject design where all the participants were exposed to each environment. Four of the studies (Igarashi et al., 2015; Song et al., 2019a, 2019b, 2020) collected data during the environmental exposure, while one study (Stigsdotter et al., 2017) collected data before and after the environmental exposure.

The studies conducted two of four environmental exposures (see Table 1): watching nature versus an urban environment or walking in nature versus walking in an urban environment. Igarashi et al. (2015) used a kiwifruit orchard landscape as a natural environment and a building site as an urban environment. The participants viewed the kiwifruit orchard from the edge while sitting down, and if they turned around, they could see the building site. However, when watching the building site, participants were seated in the shadow of a tent closer to the buildings. The kiwifruit orchard consisted of 14 trees bearing many fruits, and the leaves kept the sun away from the participants' eyes. The building site consisted of a two-story building and a well-paved road. In two of the studies by Song et al. (2019a, 2019b) 12 different locations were used: six forest areas and six city areas. The participants were divided into groups of twelve and assigned to one of each type of location. In the third study by Song et al. (2020) ten different locations were used: five forest areas and five city areas. The forest areas were well-maintained and safe, including trees such as oak, red pine, maple, and cherry. The city areas were located either near a railway station or downtown. Stigsdotter et al. (2017) used the Danish Health Forest, Octavia, an Arboretum containing the most extensive collection of shrubs and trees in Denmark for the natural environment. The walk consisted of a 750 m long trail exposed to open areas, a lake, more secluded green areas, and a pine forest. For the city environment, the walk took place in an area filled with architectonical and historical qualities in downtown Copenhagen. The city area was chosen for its historical value in maybe not being as stressful as other urban areas. The participants were transported in a minibus to both environments. Moreover, which environment the participants would visit was told on the bus. The duration of the bus ride was the same for both environments.

Watching nature as well as watching the urban environment involved a passive exposure while sitting down at each site. When walking, participants did so along a given course at an average pace of about 1km at each environmental site. The amount of time of the environmental exposure across all the studies varied from 10 to 15 minutes.

Stress Measurements

This review identified two different outcome measurements of stress: activity in the ANS measured with HRV (Holter, 1961) and cerebral activity measured by NIRS (Jöbsis, 1977). Each measurement involved one or more outcomes which are shown in Table 1.

Autonomic Nervous System

Four studies measured HRV as an indicator of ANS activity (Igarashi et al., 2015; Song et al., 2019a, 2019b; Stigsdotter et al., 2017). All four studies monitored HRV using a portable electrocardiograph. HRV was measured for its total power (TP), low frequency (LF) component, high frequency (HF) component, and low frequency/high frequency (LF/HF) ratio. Three of four studies (Igarashi et al., 2015; Song et al., 2019a, 2019b) found statistically significant differences in the participants' physiological responses between the natural and urban environment.

In the study by Igarashi et al. (2015) the mean ln(HF) value, an indicator of parasympathetic nerve activity, was significantly higher for watching the kiwifruit orchard compared to the building site. The ln(LF/HF) ratio, an indicator of sympathetic nerve activity, was lower in the kiwifruit orchard in contrast to the building site. However, the difference was not statistically significant (see Table 1).

In the study by Song et al. (2019a) the mean value of ln(HF) was significantly higher when walking in nature compared to the urban environment. The non-logarithmic HF value also showed a significant difference between the two environments, with the natural environment being higher in contrast to the urban one. These results indicate a parasympathetic activity. The ln(LF/HF) ratio was significantly lower for walking in nature compared to the urban environment. The non-logarithmic LF/HF ratio value also showed a significant difference indicating a reduced sympathetic nerve activity (see Table 1).

When the participants were sitting down instead of walking (Song et al., 2019b), they showed a significant difference in the mean value of ln(HF) between watching nature and the urban environment. When watching the natural environment, the ln(HF) was significantly higher in contrast to watching the urban one. The non-logarithmic HF values also showed a significant difference between the two environments. As in their earlier study (Song et al., 2019a), the ln(LF/HF) ratio was also significantly lower for the natural environment in comparison to the urban one. The same goes for the non-logarithmic LF/HF ratio (see Table 1).

In the study by Stigsdotter et al. (2017) that used HRV as an indicator of ANS, no statistically significant differences were shown between the mean value of ln(TP), ln(LF), ln(HF), and ln(LF/HF) ratio value when comparing the natural environments to the urban environment. However, comparing HRV measurements from the bus ride to measurements taken before and after the intervention, a significant difference shows a more prominent parasympathetic activity before and after the intervention, compared with the bus ride, indicated by the mean values of ln(HF). Furthermore, the ln(LF/HF) ratio was significantly lower before and after the intervention compared with the bus ride, and there was no significant difference between before and after the intervention.

Cerebral Activity

One study used NIRS to measure cerebral activity (Song et al., 2020). A portable two-channel NIRS device was used to measure the shifts in oxyhaemoglobin (oxy-HB) concentration. The NIRS probes are flexible, and two sensors were placed on the participants' foreheads over the right and left frontal regions.

The results of Song et al. (2020) show that the mean oxy-HB concentration was lower in the right area of PFC when watching the natural environment compared to watching the urban environment. The mean oxy-HB concentration in the left area of PFC was marginally significantly lower when watching the natural environment compared to the urban environment (see Table 1).

Table 1

Characteristics of studies that report stress outcome measurement in response to a nature intervention

First Author & Publication Date	Study Design & Location	Sample Size, Study Population & Age	Intervention	Duration of Intervention	Control Group	Outcome Measurement	Results
Igarashi et al. (2015)	Cross-over design Within-subjects Japan	17 females 46.1 (± 8.2)	Watching a kiwifruit orchard vs. watching a building while sitting down	10 min (Each site)	No	HRV	ln(HF) of the orchard (4.30 ± 0.17 $lnms^2$) was significantly higher than that of the building site (4.06 ± 0.18 $lnms^2$; p = < 0.05) ln(LF/HF) ratio of the orchard (0.40 ± 0.08) was lower than in the building site (0.51 ± 0.08; p = 0.108)
Song et al. (2019a)	Cross-over design Within-subjects Japan	60 (72) females 21.0 (± 1.3)	Walking in a forest area vs walking in an urban area	15 min (Each site)	No	HRV	ln(HF) of the forest area (4.31 ± 0.12 $lnms^2$) was significantly higher than that of the city area (3.52 ± 0.14 $lnms^2$; p = < 0.01) HF value of the forest area was significantly different (105.12 ± 14.01 ms^2) than of the city area (57.11 ± 10.36 ms^2; p = < 0.01) ln(LF/HF) of the forest area (1.58 ± 0.09) was significantly lower than in the city area (1.88 ± 0.10; p = < 0.01) LF/HF ratio of the forest was significantly different (6.10 ± 0.67) than that of the city area (8.19 ± 0.76; p = < 0.01)

Table 1 *(continued)*

First Author & Publication Date	Study Design & Location	Sample Size, Study Population & Age	Intervention	Duration of Intervention	Control Group	Outcome Measurement	Results
Song et al. (2019b)	Cross-over design Within-subjects Japan	65 (72) females 21.0 (± 1.3)	Watching a forest vs watching a city area while sitting down	15 min (Each site)	No	HRV	ln(HF) was significantly higher in the forest area (5.98 ± 0.09lnms²) than in the city area (5.46 ± 0.10 lnms²; p = < 0.01) HF was significantly different in the forest area (505.36 ± 46.75 ms²) than in the city area (313.34 ± 27.24 ms²; p = < 0.01) ln(LF/HF) was significantly lower in the forest area (0.77 ± 0.07) than in the city area (1.14 ± 0.08; p = < 0.01) LF/HF ratio values was significantly different for the forest area (2.55 ± 0.21) than in the city area (3.83 ± 0.30; p = < 0.01)
Song et al. (2020)	Cross-over design Within-subjects Japan	29 (60) females 21.0 (± 1.4)	Watching a forest vs watching a city area while sitting down	15 min (Each site)	No	NIRS	The mean oxy-HB concentration in the right area of the PFC while watching the forest was significantly lower than when watching the urban area (forest: 0.46 ± 0.19 µM; city: 0.90 ± 0.20 µM; p = < 0.05) in the left area of the PFC the oxy-HB concentration was marginally significantly lower when watching the forest area than while watching the urban area (forest: 0.70 ± 0.24 µM; city: 1.10 ± 0.24 µM; p = < 0.08)

Table 1 *(continued)*

First Author & Publication Date	Study Design & Location	Sample Size, Study Population & Age	Intervention	Duration of Intervention	Control Group	Outcome Measurement	Results
Stigsdotter et al. (2017)	Cross-over design Within-subjects Denmark	43 (51) females (20-36)	Walking in a forest area vs walking in an urban area	15 min (Each site)	No	HRV (measurement was taken before and after the intervention)	ln(TP) (Bus: 7.43 ±0.07; Before: 7.56 ± 0.11; After: 7.64 ± 0.11; p = < 0.05) ln(LF) (Bus: 6.41 ± 0.09; Before: 6.21 ± 0.13; After: 6.20 ± 0.12) ln(HF) (Bus: 5.68 ± 0.11; Before: 6.25 ± 0.15; After: 6.36 ± 0.13; p = < 0.001) ln(LF/HF) (Bus: 0.72 ± 0.11; Before: -0.04 ± 0.12; After: -0.14 ± 0.09; p = < 0.001)

Note. Abbreviations: heart rate variability (HRV); low frequency (LF); high frequency (HF); low frequency/high frequency (LF/HF) ratio; natural logarithmic low frequency (lnLF); natural logarithmic high frequency (lnHF); natural logarithmic low frequency/high frequency ln(LF/HF) ratio; natural logarithmic total power (lnTP); near-infrared spectroscopy (NIRS); oxyhaemoglobin (oxy-HB); prefrontal cortex (PFC). Sample size reported with participants in total (in parentheses), and the number of participants the data analysis is based on.

Discussion

This systematic review aimed to investigate if there is evidence that nature affects stress in women. By focusing on studies that measure participants' physiological responses while spending time in nature, this thesis aimed to get a more objective viewpoint of the field as a complement to the many studies using subjective questionnaires. This review found significant results in four of the studies that nature exposure alleviated physiological markers of stress. However, the fifth study deviated from the rest and showed no significant difference between the natural and urban environments.

The results of Igarashi et al. (2015) indicate an activation of the parasympathetic nervous system and a suppression of the sympathetic nervous system in the kiwifruit orchard compared to the building site. These results are in accordance with previous studies on men (Lee et al., 2011; Park et al., 2008, 2009, 2010) where participants watched a forest area and an urban area while sitting down.

As presented earlier, the results in the two studies by Song et al. (2019a, 2019b) indicate an activation of the parasympathetic nervous system and a suppression of the sympathetic nervous system. Similar results are found in previous studies that explored the physiological responses to a forest environment in male participants. In three studies, the participants viewed the forest in a seated position (Lee et al., 2011; Park et al., 2008; Tsunetsugu et al., 2013), and in one study, the participants were walking in the forest (Lee et al., 2014) and in three studies the participants were viewing from a seated position as well as walking in the forest (Park et al., 2009, 2010). Even though the participants were walking in Song et al. (2019a) and sitting down in Song et al. (2019b), the results were similar. However, according to Song et al. (2019b) the proportion of participants showing these physiological responses was higher for those walking in the forest compared to those sitting down and watching the forest environment.

In the most recent study by Song et al. (2020) where they used NIRS to measure the physiological responses to stress, the activity in the PFC was significantly decreased when viewing the forest environment compared to the urban environment. Similar results were found in previous studies where participants viewed a forest environment from a rooftop (Joung et al., 2015) and where participants viewed a forest while sitting down as well as walking in a forest (Park et al., 2007). A short walk in a forest environment decreased the total hemoglobin concentration in the left area of PFC (Park et al., 2007). In another all-female study (Song et al., 2018) where they used an image of a forest on a TV screen, there was a reduction in oxy-HB concentrations in the right area of PFC. The difference between these studies is that in the study by Park et al. (2007) the participants were walking in a forest, while in Song et al. (2018) they were seated and watching a TV screen, and in Song et al. (2020), the participants were seated and watched a natural forest environment. Conditions with no physical activity resulted in a shift in activity in the right area compared to the left area of PFC. Oxy-HB is affected by changes in skin blood flow from physical activity (Miyazawa et al., 2013). However, no physical activity was part of the experiment since it was performed in a seated position. Future research is needed for additional information on the mechanisms associated with the right and left areas of PFC to get a clearer picture of the differences between the two areas. Also, measuring skin blood flow simultaneously with oxy-HB concentration can further establish if physical activity influences the result.

All four studies so far have results that are linked to physiological relaxation. Activation of the parasympathetic nervous system and suppression of the sympathetic nervous system indicate a relaxed state (Kobayashi et al., 1999; Lim et al., 2021; Porges, 2007). Moreover, a decrease in brain oxygenation in the prefrontal cortex indicates that cerebral activity has attenuated, indicating a relaxed state (Park et al., 2007).

On the contrary, Stigsdotter et al. (2017) did not get a significant difference between the forest and the urban environment. Stigsdotter et al. (2017) did not measure HRV during the intervention itself as the others did. Instead, the measurements were done before, after, and during the bus ride to the two different locations. There was a significant difference between the bus ride compared to the forest environment as well as compared to the city environment. Thus, both environments were more physiologically restorative than being on the bus. On the other hand, there was no significant difference between the forest and the urban environment before or after walking in either environment. These findings contradict previous studies (Joung et al., 2015; Lee et al., 2011, 2014; Park et al., 2007, 2008, 2009, 2010; Tsunetsugu et al., 2013) and Stigsdotter et al. (2017) mention that the type of urban environment may explain the result. The choice to have an urban environment with historical and architectural values and streets with very little traffic differ from the previously mentioned studies. Previous studies have used most modern urban environments with more traffic or modern houses: according to Staats et al. (2016), the least desired urban environment for restoration. Furthermore, not measuring HRV during the intervention makes it harder to compare these results with the other included studies in this review.

Two measurements were not included in this review: EEG and cortisol. Most studies using EEG in nature/stress research use virtual reality or a forest therapy program. One study (Hassan et al., 2018) fulfilled all the inclusion criteria except the participants were both men and women. Hassan et al. (2018) used EEG to measure participants walking in either a bamboo forest or an urban environment. The results indicate that the participants were relaxed in the forest but under stress in the urban environment. Another study (Yu et al., 2016) using salivary cortisol fulfilled all criteria except that a therapy program with other elements than walking or observing nature was used. Nevertheless, the results indicate that the participants were more relaxed two and four weeks after the forest therapy program.

There seem to be no gender differences in the way women and men respond to the natural environment when comparing results from this review and earlier mentioned studies. However, according to Song et al. (2019b) men get more relaxed when watching a forest from within compared to walking in one. In contrast, women get more relaxed by walking in the forest compared to watching the forest from a seated position (Song et al., 2019b). With gender differences regarding livelihood and reproduction, men might evaluate being on the lookout as more relaxing, and women who have more responsibility for their offspring might react more relaxing when walking and searching for suitable shelter. Given the tend-and-befriend response to stress, there may be more decisive differences if the same interventions were done with a group of women. Hence, there needs to be more research on tend-and-befriend response in this area of research. Moreover, most group interventions have the help of a guide. Given the recommendation from World Health Organization to find self-care interventions that people can pursue on their own, future research should focus on designing suitable interventions for groups without the help of a guide.

Ethical and Societal Aspects

All five studies were approved by an ethics committee, and the participants signed a written informed consent in advance. None of the studies declare any conflict of interest or ethical dilemmas. There were no risks for the participants in the forest or urban environments or using the different methods in the five studies. The participants were all healthy, and none had any psychiatric or physiological disorders.

Stress is a significant problem in today's urban society, which is shown in the increasing number of stress-related illnesses causing people to go on sick leave. If nature can be a part of the solution to diminish stress and stress-related illnesses, this line of research is valuable to our society. Nature is free and available in some form to many people. Hence, the social status of people is irrelevant, making nature interventions available to almost everyone.

Limitations

There are several limitations in the included five studies. In the studies by Song et al. (2019a, 2019b, 2020) the participants were healthy young female university students, making it difficult to generalize the results. Song et al. (2019a, 2019b) only measured autonomic nervous activity as a physiological marker, which according to Yao et al. (2021) does not capture the entire stress response. Using a mean value from numerous environments makes it difficult to know if one environment is more effective in alleviating stress compared to others (Song et al., 2019a, 2019b, 2020). Igarashi et al. (2015) and Stigsdotter et al. (2017) used specific environments, and Stigsdotter et al. (2017) used a small number of participants, making it difficult to generalize the results. Also, collecting data over two seasons: spring and autumn may have led to bias due to vegetation differences in the two seasons (Stigsdotter et al., 2017). Not having a corresponding measurement in all studies makes it difficult to compare results within the field. Recruiting participants through posters and notice boards, possibly only having nature-interested people sign up for the studies, can also bias the results.

One of the most significant limitations of this review is the number of studies included. The fact that the same researchers were involved in four of five studies is an overall limitation. The number of participants in the included studies is also relatively low (three had fewer than 60 participants). Furthermore, only having one study using NIRS limited the possibility of comparing these results. Finally, this review has multiple selection biases: including direct exposure only, not addressing laboratory environments of nature like VR or pictures, only choosing open access articles or articles accessed via the school library, and only including articles published in the English language.

Future Research

Future research should include more participants ranging from all age groups to be more representative of the population. Furthermore, the tend-and-befriend reaction to stress should be researched using group settings with single participant control groups to compare the results. Future research is also needed to separate the different environments and find the best-suited ones for future interventions. Further, regarding Stigsdotter et al. (2017) there also needs to be research to explore the different urban environments.

More research is also needed using physiological markers of stress out in the natural environment and not measured in a laboratory using virtual reality. Although virtual reality may help relieve stress, being out in the natural environment adds to the importance of caring for the natural environment for future generations. Additionally, testing out different lengths of interventions and comparing these against each other, and doing follow-up testing to see how long-lasting the effect of nature is on the participants, is another aspect to consider for future research.

According to Yao et al. (2021) stress is impossible to measure using only a single marker due to its complex networks. This review found only five studies using physiological markers to measure stress in women, and none of them used EEG or salivary cortisol, and very few exist at all that use EEG together with other methods out in natural forest environments. With this lack of different physiological measurements, future research needs to broaden its use of physiological measurements. Additionally, the framework needs to be more cohesive throughout the field when using these measurements.

Conclusion

This review showed that nature alleviates stress in women, similar to previous research on men, and adds to the existing knowledge of the effect of nature exposure on women's stress. Hence, supporting the biophilia hypothesis, stress reduction theory, and attention restoration theory. On a societal level, physicians and policymakers should be aware of the importance of this knowledge. Physicians when planning for prevention or treatment for many of the illnesses that follow from stress and policymakers when planning new city landscapes and the importance of access to natural environments. Stress-related illnesses could be a less frequent cause of sick leave in women if more elements from nature were included in urban environments. On an individual level, the present review contributes to the growing body of evidence suggesting that nature exposure is an evidence-based intervention effective in alleviating stress in women.

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