

Written Dissertation
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The impact of physical activity/exercise on physiological and psychological health in natural and indoor environments: A narrative review

Abstract

An increasing amount of research is exploring the potential additional health benefits of exercising outdoors versus indoors (Noseworthy *et al.*, 2023). This narrative review investigated the effects of natural environments on physical and mental health compared to indoor environments. The review included cross-sectional studies, non-randomised controlled studies, randomised studies, and peer-reviewed studies, and seven electronic databases were searched, including GreenFile, Science Direct, Academic Search Premier (EBSCOhost), PubMed (National Library of Medicine and National Institutes of Health), Google Scholar, Sports Discus, and MEDLINE. The findings of this review highlight the potential benefits of physical activity and exercise in natural environments while recognising the complexities and contradictions of the existing literature. Furthermore, the physiological findings suggest that exercising outdoors in natural environments may reduce blood pressure and improve cardiovascular health. Sunlight exposure increases the production of Vitamin D, and the findings suggest that outdoor physical activity can effectively increase vitamin D levels, potentially contributing to enhanced mental health and mood regulation. Several studies found that outdoor exercise reduced perceived stress, improved mood states, and alleviated symptoms of depression and anxiety. However, some inconsistencies were detected. A few studies have yet to find significant differences between indoor and outdoor environments regarding mood and stress outcomes. The research explored different types of nature exposure (e.g. videos, virtual reality) and found actual outdoor settings often provided greater psychological and emotional benefits. Outdoor exercise may also facilitate social connectivity and a sense of belonging to nature. These findings have practical implications across various areas. Health promotion programs can encourage outdoor physical activity through park-based exercise classes or hiking clubs. Urban planners can prioritise green space creation, promoting outdoor exercise. Clinical interventions can include outdoor exercise prescriptions for better cardiovascular health and emotional well-being. Therefore, Future research should investigate the long-term impacts of outdoor physical activity on cardiovascular health and mental well-being, dose-response relationships, population-specific effects, influence of different natural environments, comparisons with indoor exercise settings, and physiological and psychological mechanisms underlying benefits of outdoor exercise. This can inform personalized solutions and evidence-based policies promoting healthy living and environmental sustainability.

Introduction

Exercise and physical activity are widely acknowledged as effective ways to improve psychological and physical health (Biddle *et al.*, 2021). Physical activity is any bodily movement produced by skeletal muscles that requires energy expenditure (Caspersen, Powell and Christenson, 1985a). On the other hand, exercise is a part of physical activity with the end or intermediate goal of maintaining or improving physical fitness; it is organised, structured, and repetitive (Caspersen, Powell and Christenson, 1985b). Hu *et al.* (2020) state that participating in physical activity and exercise provides immediate positive effects on mood, reduces depression and anxiety, and offers physiological benefits such as lower risks of chronic diseases and improved body composition (Rueggsegger and Booth, 2018).

Despite recognising the importance of physical activity and exercise, physical inactivity is a growing concern (Haseler and Haseler, 2022). According to the United Kingdom Government (2022a), physical inactivity is responsible for one in every six deaths in the United Kingdom (UK). Moreover, it is predicted to cost the UK £7.4 billion annually, including £0.9 billion for the National Health Service (United Kingdom Government 2022b). The adverse effects that physical inactivity can impose on both physical and mental well-being are becoming increasingly apparent as inactivity rates continue to rise. According to Hallal *et al.* (2012), the burden of physical inactivity continues to increase as over 35% of the worldwide population fails to fulfil the required Physical activity guidelines.

Furthermore, researchers are now exploring the potential differences between exercising in natural, green environments instead of indoor environments (Shanahan *et al.*, 2016). According to Calogiuri and Chroni (2014), a natural environment is any open area outside where a person can be close to natural features like trees, plants, grass, mountains, and water bodies. On the other hand, an indoor environment is situated inside an enclosed area with man-made features (Gomes, Delazari and Schmidt, 2021). Outdoor activities such as running, jogging, trail walking, biking, or gardening can bring numerous benefits, as the natural environment can impact an individual's well-being through variables such as fresh air and natural scenery (Brown, Schebella and Weber, 2014).

Despite the benefits of exercising outside, some people may hesitate due to perceived impediments (Lovell, El Ansari and Parker, 2010). However, personal characteristics and cognitive processes might substantially define an individual's choice for a specific environment (Bandura, 2006). In addition, people are migrating to urban areas more than rural areas, leading to increased urbanisation and a lack of access to green and blue spaces (nature deficit) (Grigoletto *et al.*, 2021). The research by Focht (2009a) carried out a study that found that regular physical activity and exercise in a natural environment may have a more significant psychological impact than indoors. The results suggest that walking outdoors provides greater affective and motivational benefits than walking indoors on a treadmill. This has implications for promoting walking and physical activity. In addition, Gladwell *et al.* (2013) state that participating in physical activity/exercise in the natural environment

has many benefits, such as an immediate positive effect on mood and a reduction in depression and anxiety.

During the COVID-19 pandemic, individuals had to stay indoors due to government restrictions (Brown, Ferguson and Barber, 2022). According to Hailey *et al.* (2022), The research found that the level of physical activity during that time decreased, which was worrisome since physical inactivity was already an issue. Ugolini *et al.* (2020) state that although there were restrictions during the COVID-19 pandemic, physical activity in urban green spaces was still significant. In addition, Schweizer *et al.* (2021) carried out a study based in Germany, which found an increase in outdoor cycling in urban green spaces due to benefits compared to indoors during COVID-19. According to Das and Gailey (2022), green exercise significantly impacted mood, measured using a 4-item Patient Health Questionnaire (PHQ-4). The scores of those who exercise outdoors were more significant than those who exercise indoors. Recent research has found that combined training (aerobic and resistance training) in a natural environment brings out immediate physiological benefits, such as improved blood pressure, which correlates with better cardiovascular health (De Moraes *et al.*, 2022). Due to the many research papers and various opinions on the topic, a literature narrative review will be conducted.

The purpose of this narrative review is to critically review the impact of exercising indoors compared to the outdoor environment and discuss the existing evidence about the importance of participating in exercise or physical activity in each environment mentioned, which would promote a healthier lifestyle and overall well-being, and to summarise the data while identifying the gaps in the pieces of literature. Most importantly, the findings gathered from this review will immensely benefit mental health advocates or practitioners by helping persons or clients choose the right environment to engage in regular exercise or physical activity to lower the chance of developing a mental health disorder while also enhancing their mood. The findings may also aid policymakers in deciding which public infrastructure projects, such as parks and outdoor leisure areas, are facilities for the public to access. Finally, the practical implications would be determined by the specific results of the review and how they are perceived and implemented by various parties. Therefore, the aims of the narrative review are the following:

Discuss the impact of physical activity and exercise in indoor and natural environments on adults.

Explore if there are more benefits to exercising or being physically active in natural habitats than in indoor environments

Explore if chronic and acute exercise influence the proposed benefits of exercise and physical activity in indoor environments compared to natural environments.

To investigate whether factors such as intensity, duration, mode (type), and frequency of exercise and physical activity influence the potential benefits derived from performing exercise in natural environments.

Method

A narrative literature review was conducted to provide a preliminary overview of the literature on the effects of exercise and physical activity in natural environments compared to indoor environments. The initial review aimed to understand the topic and identify the critical points of existing research.

Research strategy

The following electronic databases were searched for studies: GreenFile, Science Direct, Academic Search Premier (EBSCOhost), PubMed (National Library of Medicine and National Institutes of Health), Google Scholar, Sports Discus and MEDLINE. An electronic database will be used since many credible journal articles are mainly related to the topic (Hamilton, Shephard and Stapley, 2011). The databases were carefully chosen for their comprehensive collection of resources related to the topic, including environmental, exercise, and psychological resources. Additionally, they provide updated journal articles to ensure the information is relevant and current. This selection process ensures that users can access high-quality information from reliable sources to support their research and learning. While looking for journal articles, the principal terms used were the effects of exercise/physical activity in natural environments compared to indoor environments. The words outdoor and indoor may be shown in some articles, but those articles would still be accepted due to the words' meanings being the same. Also, the term green exercise will be used in some articles, which will be accepted during data analysis. After finding the relevant studies associated with the title, a few questions were addressed to determine what the research paper is about. The authenticity of all research papers will be checked by doing additional background checks on the publisher and author. The main words that will be used are associated with the environment (natural environment or indoor environment).

Eligibility criteria

To be selected for inclusion, studies had to be original articles written in English and fall into one of three categories: cross-sectional studies, randomized control trials, non-randomized clinical trials, and literature reviews. Any duplicated research was removed. Due to this screening process, only relevant and high-quality research was included.

Data analysis

The method for gathering data entails using articles that comply with particular criteria. All the articles' texts must be accessible and examined, ensuring the data collected is extensive and detailed. After selecting studies, the data found was collected and recorded to review the information collected critically. This narrative review was divided according to the main findings of the impacts of physical activity and exercise on natural environments versus indoor environments and the factors that may contribute to the effects.

Ethical considerations:

The nature of this study is a review of multiple literature, which means that no contact will be made with people. Therefore, there is no need to conduct an ethics form (Moyers, Abildso and Kelley, 2022)

Discussion

Effects of Exercise Outdoors Compared to Indoors:

The effect of exercise and physical activity on general health has received extensive research from a variety of fields. One exciting component being investigated is how the environment in which exercise occurs—natural outdoor settings versus regulated indoor environments—influences both physiological and psychological health results. This narrative review aims to illuminate and evaluate the impacts of exercise in natural surroundings vs indoor environments on key health outcomes such as vitamin D production, cardiovascular health, mood states, and connection to nature.

Cardiovascular Health

Regular physical activity and exercise are critical for maintaining cardiovascular health and lowering the risk of cardiovascular illnesses (Lavie *et al.*, 2019). Despite advancements in medical treatments, cardiovascular diseases remain the leading cause of morbidity and mortality globally (Nystoriak and Bhatnagar, 2018). According to the World Health Organisation (2023), an estimated 17.9 million people die from cardiovascular disease each year.

Therefore, exploring the different types of physical activity individuals can engage in to improve cardiovascular health is crucial. Mieras, Heesch, and Slivka (2014) conducted a study to compare the physiological and psychological responses of 12 male cyclists during indoor and outdoor cycling. The results showed that outdoor cycling, also known as green exercise, resulted in a higher heart rate than indoor cycling in a laboratory setting. A higher heart rate during exercise typically indicates a greater demand for oxygen and energy, which can lead to improved cardiovascular fitness over time (Boyette and Manna, 2019). In contrast to Niedermeier *et al.* (2017) a randomised control trial conducted a study on mountain hiking and treadmill walking in a fitness area in Innsbruck. The research aimed to measure the rate of perceived exertion (RPE) and heart rate. The study found that when the average heart rates were expressed as a percentage of the maximum heart rate (% HRmax), the difference between the two conditions was minimal, with the mean being 59% for outdoor hiking and 57% for treadmill walking, suggesting that both exercises had the same effect on the cardiovascular system. Generally, exercise in the 50-70% HRmax range is considered moderate intensity and benefits cardiovascular conditioning (Ito, 2019).

In addition, Focht (2009b) found no difference when measuring the heart rate and RPE using Borg's 15-point RPE scale (Borg, 1998), a 10-minute walk inside a laboratory on a treadmill compared to an outdoor setting. Exercising at the right intensity is crucial since intensity affects how hard the heart works during exercise (Beckie *et al.*, 2014). One way is using RPE (Morishita *et al.*, 2018). This is a subjective measure that helps researchers and participants understand exercise intensity. By aligning exercise intensity with RPE levels, individuals can ensure they exercise within the target range for cardiovascular benefits such as improved heart health, blood circulation, and overall fitness (Alsamir Tibana *et al.*, 2019). Pinckard,

Baskin and Stanford (2019) state that moderate-intensity aerobic exercise improves cardiovascular health. Blood pressure shows a circadian rhythm with different levels at different times (Douma and Gumz, 2018). Blood pressure levels fluctuate in a predictable pattern over the 24-hour cycle (Sheng *et al.*, 2013). Valdez (2019) stated that the lowest readings typically occur during the overnight sleep period in the early morning hours. As the day progresses and people become active, blood pressure gradually rises. Daily activities like exercise and mealtimes can further impact these fluctuations.

Li *et al.* (2011) reported that walking in a forest park but not in an urban area significantly reduced both systolic and diastolic blood pressure in male middle-aged subjects. Another study by Navalta *et al.* (2019) compared five different environments, indoor exercise lab, busy outdoor intersection, sea level outdoor, green outdoor trail, brown outdoor trail, and outdoor trail below sea level. The desert and green environment provided similar benefits to subjective measures like calm and comfort but did not differ in heart rate, blood pressure or perceived stress measures. The research has limitations because of the limited number of participants (n=10) and the probable absence of acclimatisation to the different environmental conditions. The study may have been impacted because the human body requires time to adapt to extreme heat, dry air, and substantial sunlight exposure (Marriott, 2016). The body can produce vitamin D when exposed to sunlight, but this process is affected by various factors such as the time of day, season, geographical location, and skin colour (Tsiaras and Weinstock, 2011). Recent studies suggest that outdoor exercise may be more beneficial for vitamin D production than indoor exercise (Bârsan *et al.*, 2023).

Vitamin D production

Vitamin D is crucial for various physiological functions in the body (Carswell and Fraser, 2022). Its production is primarily associated with exposure to sunlight and oral supplementation (Wacker and Holick, 2013). According to Kawashima *et al.* (2021), outdoor athletes a significantly lower vitamin D levels ($P < 0.001$) compared to indoor athletes. Despite the findings, the study had 48 participants which is a small sample size, more research should be done with a larger sample size. Maruyama-Nagao, Sakuraba and Suzuki (2016) reported that athletes in indoor sports were more likely to have insufficient vitamin D levels than those in outdoor activities. This was especially true throughout the cold months. The study's findings, which imply a higher risk of vitamin D deficiency in indoor athletes, may have been influenced by data obtained during the winter months (Ringe and Kipshoven, 2012).

The advantageous effect of vitamin D produced by sunlight exposure on mental health has been reported in previous studies (Annweiler *et al.*, 2013). In the study by Irandoust and Taheri (2017a), whose participants were 75 obese Iranian women, the study found that women who are both obese and depressed with low levels of serum 25(OH)D can experience an improvement in their depression symptoms and vitamin D deficiency by taking vitamin D supplements and engaging in exercise, especially outdoors. This highlights the importance of maintaining a healthy lifestyle to combat the adverse effects of obesity and depression. Furthermore, recent research has

suggested that vitamin D may affect mood and reduce stress. Studies have found that people who are deficient in vitamin D are more likely to experience symptoms of depression and anxiety. In contrast, supplementation with vitamin D has been shown to improve mood and reduce stress levels.

Farrokhyar *et al.* (2015) conducted a systematic review and stated that the risk of vitamin D sufficiency significantly increases in higher latitudes, in winter and early spring seasons, and for indoor sports activities. Regular investigation of vitamin D status using reliable assays and supplementation is essential to ensure that athletes are healthy. In contrast, Aydin *et al.* (2019) conducted a study on athletes and stated that additional supplements are recommended whenever necessary. No statistically significant relationship was found between gender, indoor/outdoor sports participation, and vitamin D levels. However, the winter season had adverse effects on vitamin D levels. Therefore, adequate precautions should be taken to increase vitamin D, especially during winter, to maintain the best participation. Further studies are needed to evaluate vitamin D deficiency related to seasonal and indoor/outdoor sports.

Mood and Stress Reduction and exercise in nature

Engaging in physical activity releases endorphins, which are natural chemicals that help boost mood and promote feelings of relaxation (Mahindru, Patil and Agrawal, 2023). Research has shown that spending time in nature can have a positive impact on both mood and stress levels. Combining this with regular exercise can be a powerful way to improve overall well-being. According to Gaekwad *et al.* (2022) humans are biophilic which means they tend to connect with nature leading to a boost in mood and as a result reduced stress (Berto, Maculan and Barbiero, 2020).

Klaperski *et al.* (2019) conducted a study of 140 participants 18 years and older. The participants were divided into two groups: indoors and outdoors. The indoor group activities included aqua aerobics, swimming, basketball, fencing, and volleyball. The outdoor group activities were running, football (played on a green lawn with a river and forest adjacent), and mountain biking and running (in a hilly forest with little to no urban views). All exercises lasted 1 to 2.5 hours. Before and after the activities, participants completed the Multidimensional Mood State Questionnaire (Klaperski *et al.*, 2019) to measure calmness and the Perceived Stress Scale (Cohen *et al.*, 1983; Klein *et al.*, 2016). The study found that exercise led to a reduction in mood and stress; the study did not find any greater benefits in green exercise environments compared to indoor environments; they also found that different types of exercise, running outdoors in particular, had a more significant impact on mood and perceived stress levels. A study conducted by Turner and Stevinson (2017) involved 20 participants who exercised in a green woodland area and a gym treadmill. The study measured the data at three intervals: 3000m, 6000m, and 10 minutes post-exercise. The results indicated that regular runners experienced positive feelings during and after high-intensity exercise in natural outdoor environments and indoor fitness centres.

Furthermore, Bramwell, Streetman and Besenyi (2023) conducted a four-week, two-arm randomised controlled study. They compared two group exercise classes: one held in an indoor dance studio and the other in an outdoor grassy field environment in the United States. The exercises included walking and resistance band exercises, and perceived stress was measured using the Perceived Stress Scale (PSS-4). The study's findings show that although both environments reduced perceived stress, the outdoor grassy field environment resulted in a greater reduction of perceived stress compared to the indoor group. However, a limitation of this study is the small sample size and measurement of stress biomarkers.

The study by Janeczko *et al.* (2020) involved 75 students aged 19-24 years from the Warsaw University of Life Sciences. The study divided students into groups exposed to different environments: apartment suburbs, green suburbs (more greenery), coniferous forests, and deciduous forests. However, the study did not find a significant influence of the surroundings on the change in mood among participants. Regardless of whether the exercise took place in urban settings or forest areas, the participants experienced similar levels of positive and negative feelings.

Rogerson *et al.* (2016a) conducted a study involving 24 participants divided into pairs. The study had three conditions: outdoor sports fields with grassy areas and trees, an indoor laboratory setting with white walls, and a baseline condition. The conditions were completed on separate days, with the baseline being counterbalanced and randomised. All environments used CatEye ergocycles, where the intensity was controlled. The study used the shortened version of mood states to measure moods. The study found that outdoors would lead to greater mood improvements, exercise enjoyment, or intention for future exercise compared to indoors.

Depression and anxiety

The study by Legrand, Race and Herring (2018) involved 18 participants (12 women and six men) with elevated depressive symptoms recruited from a subsidised housing complex in Reims, France. A within-subject design was used with three counterbalanced conditions: outdoor exercise (20-minute run in Verzy Regional Nature Park), indoor exercise (20-minute run at the University of Reims gym), and a sedentary control condition (watching a 20-minute educational movie). Exercise intensity was at 64-77% of age-specific maximum heart rate. Depressive symptoms were assessed using the Beck Depression Inventory-II. At the same time, feelings of energy and fatigue were measured before and after each condition using the vigour and fatigue subscales of the Profile of Mood States. The study aimed to compare how outdoor exercise, indoor exercise, and sedentary activities influenced subjective energy and fatigue levels in individuals experiencing depressive symptoms. The results found that exercise improved feelings of energy in depressive symptoms adults, but it did not matter whether exercise occurred indoors or outdoors. Outdoor environment ($t_{(17)} = 3.19, p = .005$) and Indoor environment ($t_{(17)} = 2.34, p = .032$), which suggests that there were significant differences before and after an exercise session.

However, contrary to previous reports suggesting an additional benefit of exposure to nature during exercise in participants with depressive symptoms. For instance, Frühauf *et al.* (2016) conducted a study which included 14 patients with mild to moderate depression (8 females, six males, mean age 32.7 years). The study had three conditions: sedentary control, indoor ergometer cycling at moderate intensity, and outdoor green environment Nordic walking. Each condition lasted 60 minutes and was conducted as a group within two weeks. The Feeling Scale, Felt Arousal Scale, and Rating of Perceived Exertion (RPE) were measured periodically, while the Mood Survey Scale was measured pre- and post-condition. It was found that indoor conditions tended to reduce anger more than Sedentary conditions ($p = .058$, $d = 1.16$), which suggests that it was not significant. Outdoor conditions reduced depression more than sedentary conditions ($p = .042$, $d = 1.08$), suggesting a significant difference and Outdoor conditions tended to reduce fatigue more than Sedentary conditions ($p = .056$, $d = 1.16$). The difference was not significant. Although Irandoust and Taheri (2017b) investigated vitamin D supplementation in obese women, the participants were depressed, and the study was assessed using the Beck depression inventory; it was found that individuals who took Vitamin D supplements and engaged in outdoor physical activity showed a more significant improvement in their depression levels than other groups. Interestingly, there were no significant differences in depression levels between those who engaged in indoor physical activity with Vitamin D and those who engaged in outdoor physical activity with Vitamin D, indicating that outdoor physical activity may play a key role in improving depression. The study had many limitations, such as a low number of participants and limited generalisability of the results to obese, depressed women. Additional studies involving more subjects, a more controlled environment, and various psychological tests are required to make conclusive assumptions about a larger population.

Lacharité-Lemieux, Brunelle, and Dionne (2015) conducted a study on 23 healthy women who had reached menopause. These women participated in three identical weekly resistance and aerobic training sessions, each lasting an hour. The study aimed to measure Adherence, affective valence (Feeling Scale), affective states (Exercise-Induced Feeling Inventory), and perceived exertion ratings during exercise sessions. The focus of the study was depression symptoms. The study found that only the outdoor group exhibited decreased depression symptoms and increased physical activity levels ($P \leq 0.01$ and $P \leq 0.05$, respectively).

Numerous studies have highlighted the mental health benefits of spending time in nature and participating in nature-based interventions. In a systematic review, Coventry *et al.* (2021) found that interventions like forest therapy, wilderness therapy, gardening, and green exercise showed improvements in mental health outcomes across all populations studied. These interventions helped reduce depressive symptoms, anxiety, and negative affect and enhanced positive affect. Stanton and Reaburn (2014) also stated that for depressed individuals, exposure to natural environments can be therapeutic. When it comes to specific mental health measures, Lawton *et al.* (2017) reported that individuals engaging in outdoor physical activity experienced lower levels of somatic anxiety compared to those

exercising indoors. However, they found no significant differences between the outdoor and indoor groups in terms of overall trait anxiety, cognitive anxiety, or psychological well-being levels. This suggests being outdoors may specifically help reduce physical symptoms of anxiety.

The research by Weng and Chiang (2014) conducted a study, (internet surfing, indoor chatting, walking, exercising, outdoor gardening) that was chosen for college students to engage in for 30 minutes each. The participants' attention restoration and state anxiety were measured using the Necker Cube Pattern Control test and the State Anxiety Inventory, respectively. The results stated that Chatting with friends and walking significantly reduced anxiety levels with large effect sizes. Still, compared to indoor and outdoor environments, the two-way ANOVA analysis indicated no significant impact of the environment (indoor versus outdoor) on reducing anxiety levels. However, the results showed that there was a significant difference ($F(1, 201) = 3.53, p = .02$) in the attention restoration between the outdoor activities (average score of 2.85) and the indoor activities (average score of 3.70). This indicates that the attention restoration of the outdoor activities was lower than that of the indoor activities. It is important to note that Lower scores are indications of more directed attention capacity. Hence, there was a significant interaction between environment and time for attention restoration, with outdoor activities showing greater benefits.

Cognitive performance

Regular physical exercise has been found to enhance cognitive function and overall brain health (Mandolesi *et al.*, 2018). However, the setting where the exercise occurs can play a pivotal role in the level of effectiveness (Taylor *et al.*, 2016). Factors such as ambient noise, lighting, temperature and air quality can significantly impact the brain's ability to process information and retain memory (Hsu and Bai, 2022). Therefore, Sallis (2009) stated it is crucial to consider the environment when choosing the location for physical activity.

The study by Boere *et al.* (2023) involved 30 undergraduate and graduate students engaged in a visual oddball task. Their electroencephalogram (EEG) data was recorded separately before and after 15-minute indoor and outdoor walks. Each participant underwent two 2 km walks (indoor and outdoor) on separate days, with EEG data and task performance recorded before and after each walk. The study revealed that amplifying the P300 ERP component is linked with better attention and working memory. Nonetheless, this outcome was only noticeable after engaging in outdoor physical activity, not indoor exercise.

Kaplan (1995) proposed the Attention Restoration Theory, which suggests that natural environments create a feeling of being away from daily routines and induce a state of "soft fascination." This theory argues that nature can improve mental abilities and enhance cognitive performance instead of overwhelming attention. There were limitations in the study. For instance, the participant's heart rate was not monitored, which means that the RPE was not assessed, suggesting that the variability and the validity of the results were not controlled. Chang *et al.* (2012) had contradicting results: acute exercise can have differential effects across the attention networks,

with benefits primarily seen for executive control processes under high cognitive load. The study conducted by Rogerson *et al.* (2016b) found that environmental settings during the exercise of different modes, in various social settings, and without actual or simulated movement through the environment can facilitate attention restoration. However, the study also noted that directed attention worsened in indoor conditions, contrary to previous research, and it does not support the idea that exercise generally promotes directed attention improvements.

Another study conducted by Cassilhas *et al.* (2021) revealed that indoor aerobic exercise was more beneficial for cognitive improvement and enhanced brain-derived neurotrophic factor (BDNF) levels in older adults than outdoor exercise. This was attributed to indoor environments having lower pollution levels than outdoor environments. Bailey *et al.* (2018) found that outdoor walking sessions induced a meditative state compared to indoor sessions. Fiegen and Breitenbecher (2018) demonstrated that individuals who engaged in physical activity and those who conducted their activities in open spaces experienced enhanced positive emotions, higher energy levels, and lower exhaustion levels than those who rested or remained indoors. However, there was no significant difference in changes in attention or negative emotions between those who rested and those who exercised or between those who conducted their activities indoors and those who did so outdoors.

Type of Natural Interaction

The association between nature and human well-being has sparked increased studies in various sectors, including psychology, public health, and environmental research (Phillips *et al.*, 2023). Due to urbanisation and reliance on technology, the connection between humans and nature is gradually lost (Cox *et al.*, 2017). Understanding how varied environmental stimuli, particularly nature-based settings, impact physical and emotional health is vital for achieving holistic well-being (Liu and Green, 2023). Several studies have looked into the effects of outdoor activities on people's physiological and mental states, frequently comparing them to indoor or urban environments or other forms of nature entertainment.

The study conducted by Yeh *et al.* (2017) aimed to compare the physical and emotional benefits of nature-based exercise versus self-selected entertainment in a group of 30 individuals, consisting of 18 males and 12 females, with a mean age of 27.5 years. Among these participants, 24 exercised regularly for more than 150 minutes per week, while 6 did irregular or light exercise. The study compared three conditions: 1) static nature image, 2) dynamic nature video (Sheffield Botanical Gardens), and self-selected entertainment, such as listening to music and watching television. The study measured heart rate, distance covered, and emotion, with heart rate measured using a polar heart rate watch and emotion calculated using the Sports Emotion Questionnaire (SET).

The study's findings indicated that self-selected entertainment resulted in larger physical advantages, as participants ran longer distances at higher heart rates than nature-based conditions (static and dynamic nature images). However, the two nature-based exercise conditions were associated with higher happiness levels than

self-selected entertainment. All conditions resulted in decreased anger, dejection, and anxiety and increased exhilaration following the run.

In addition, Greco *et al.* (2023) conducted a similar study of 26 healthy individuals aged between 19 and 30, chosen from the University of Bari in Italy, comprising 12 females and 14 males. The study compared outdoor walking to indoor walking with virtual reality and indoor walking without virtual reality. The results indicated that outdoor walking caused greater cardiovascular exertion than indoor conditions. Participants also reported higher enjoyment levels for outdoor walking, whereas indoor walking with virtual reality and indoor walking without virtual reality were less enjoyable. The mindfulness experiences were similar for indoor walking with virtual and outdoor walking but different for indoor walking without virtual reality. The study's findings should be considered in light of its small sample size, which may introduce biases that could constrain the generalisability of the results to a wider population. Therefore, there is a need for future research with broader participant diversity. In contrast, a study conducted by Akers *et al.* (2012) used visual colour perception while participants exercised by watching a green outdoor environment, the same one with a grey colour and the same video with a red filter. A study showed that people who watched a green-tinted video of a natural environment experienced a lower mood disturbance and perceived exertion than those who watched red or grey-tinted videos. This implies that the colour green may play a role in the positive psychological benefits of "green exercise". Contributes to the positive psychological effects of "green exercise".

On the other hand, Browning *et al.* (2020) examined changes in mood, environment restoration, and physiological arousal following exposure to outdoor nature, virtual reality nature simulation, and an indoor control condition. Outdoor nature increased good affect, but virtual reality nature retained positive affect, as opposed to the indoor control, which decreased it. Both outdoor and virtual reality nature were assessed as similarly restorative, resulting in physiological arousal and pleasant mood. Despite the results, the participant's age variation is limited since it is primarily young adults. Therefore, it is not guaranteed that older adults would have the same response. Pasanen, Tyrväinen and Korpela (2014) surveyed 3060 participants aged 17-74. The survey assessed outdoor recreational activities in green, blue, and white settings and evaluated emotional well-being, perceived overall health, and sleep quality. Physical activity factors were also considered. Physical activity in nature was strongly connected with higher emotional well-being than activity in developed environments, even after controlling for overall activity level and life events. This confirms a prior study by Bowler *et al.* (2010) relating green activity to improved mental health. Physical exercise outside (not necessarily in nature) was positively associated with improved reported overall health, consistent with studies relating greenspace proximity to general health. Most models showed a weak positive link between physical exercise in nature and improved sleep quality, but not the final model, indicating that other factors may mediate this relationship.

The study included 331 participants (180 males, 151 females, average age 40.8 years) recruited from four United Kingdom parkrun event locations. The settings were chosen to represent a variety of traditional green workout environments,

including the beach, grasslands, riverfront, and heritage park. Data was collected on four dates at each location between September and November 2013. Participants filled out questionnaires before and after the 5k park run, which assessed self-esteem, perceived stress, mood, nature-relatedness, motivation to participate, and satisfaction. The study employed a mixed between-within design, evaluating outcomes across four distinct environment types.

Moreover, The Rogerson *et al.* (2015) study involved 331 volunteers aged 40.8 years, selected from four different parkrun event locations in the United Kingdom. Data was collected on four different dates between September and November 2013. The participants completed questionnaires before and after the 5k run, measuring their self-esteem, perceived stress, mood, nature-relatedness, motivation to participate, and satisfaction. The study aimed to assess outcomes across four distinct environment types. The study found significant improvements ($p < .001$) in acute psychological well-being measures (reduced stress, improved mood, increased self-esteem) after the parkrun exercise across all four green environment types. The research highlights the significance of incorporating nature exposure and outdoor physical activities into our daily routines to promote well-being. This is particularly important in a world increasingly dominated by technology and urbanisation. Further examination, utilising diverse participant groups and longitudinal studies, could yield a more comprehensive understanding of these connections. By participating in outdoor physical activities, such as the park run, in green spaces, individuals can contribute to their social well-being and sense of belonging in nature.

Social connectivity in nature

Nature connectedness refers to an individual's affiliation with nature (Martin *et al.*, 2020). It is a feeling of being part of the natural world as if it were an extension of oneself. A sense of belonging, acceptance, and inclusion underpins this connection. It is also characterised by embeddedness, which refers to the idea that humans are an integral part of nature and that their lives are intertwined with the natural world. Beery *et al.* (2023) mentioned that people and groups can feel disconnected from nature in various ways. Such disconnection can be experienced through anxiety, ecosystem disservices Escobedo, Kroeger and Wagner (2011), fear of nature, conflicts between humans and wildlife, nature deficit disorder, crime, virtual nature experiences, and radical landscape changes/solastalgia (Beyer *et al.*, 2014; Elliott *et al.*, 2020; Escobedo *et al.*, 2011; Galway *et al.*, 2019; Ives *et al.*, 2016; Lapointe, 2020; Soga & Gaston, 2022).

According to Nisbet, Shaw, and Lachance (2020), walking promotes some positive mood states, such as feeling contemplative, while decreasing negative moods, such as agitation, with potentially greater mood benefits from the park environment. Participants also perceived the park as more fascinating, relaxing, pleasant, and compatible with their preferences than the gym, suggesting they viewed it as a more restorative setting. Likewise, Sundgot-Borgen *et al.* (2022) conducted a study in Norway to explore the relationship between body image and nature exposure. Data was gathered from 360 adults aged 18 or above through an online questionnaire

measuring various aspects such as demographics, physical activity levels, connectedness with nature, self-compassion, and body appreciation. There was no significant difference between using fitness centres and nature in explaining body appreciation variance. After controlling for age and gender, the positive correlation strengthened between using fitness centres and body appreciation but reduced connectedness with nature and using nature for physical activity. Connectedness with nature also played a role in explaining body appreciation variance following self-compassion.

In addition, Plante *et al.* (2006) conducted a study involving 112 university students to evaluate their mood states, enjoyment of physical activity, and social desirability. The students were given various questionnaires to complete before and after; they were asked to walk briskly outdoors and on a treadmill while watching a virtual reality video of the same route. They were also asked to sit and watch the same 20-minute virtual reality video without exercising. The study concluded that energy levels were increased by virtual reality and exercise, particularly for female participants after outdoor exercise. Participants found outdoor exercise the most enjoyable condition, while virtual reality alone was the least enjoyable, especially for females. Outdoor exercise increased energy levels, while indoor exercise was more relaxing and calming. The findings suggest that virtual reality can enhance some mood benefits when combined with exercise and that exercising indoors, compared to outdoors, produces different psychological effects. Limitations included the small sample size, homogenous student population, and using a flat-screen virtual reality system rather than more immersive technology. Effect sizes were relatively small, so while statistically significant, the effects were not as large as hoped. Future research should use better virtual reality technology, explore additional conditions, and incorporate more measures to understand how virtual reality and the environment impact the psychological exercise experience.

Moreover, Flowers, Freeman and Gladwell (2018) A mixed-model design was used in a research study to investigate the effects of cycling in green environments versus indoor environments, with and without a video promoting the benefits of green exercise. Sixty undergraduate students were randomly assigned to four groups and cycled at moderate intensity for 15 minutes. The green treatment involved cycling outdoors on a sports field, while the indoor treatment involved cycling in a lab facing a blank wall. In the expectancy manipulation, one group watched a 3-minute promotional video highlighting the benefits of green exercise. In contrast, the other group did not watch the video and was the control condition.

The results reinforced the psychological benefits of green exercise compared to indoor exercise, which aligns with prior research (Plante *et al.*, 2006). Notably, showing participants a video promoting the advantages of green exercise enhanced the positive effects on vigour and self-esteem for those who exercised outdoors - a positive expectancy effect. Conversely, the video suppressed post-exercise vigour for indoor exercisers, potentially due to dissonance from missing out on the anticipated green exercise benefits - a negative expectancy effect. These expectancy effects may partly stem from pre-conditioning, as participants already had favourable attitudes and experiences with green exercise beforehand. However,

attitude changes did not mediate the effects, suggesting other psychological or neurological mechanisms. Demand characteristics could have influenced the self-reported effects. The findings underscore considerations for research design regarding pre-existing conditioning and expectations and caution against promoting specific exercises without providing adequate access. Limitations included subjective measures, an artificial outdoor setup, lack of complete blinding, and a sample with moderately high baseline green exercise levels. Future studies could use neurophysiological measures to elucidate mechanisms, improve blinding, and account for environmental factors in understanding green exercise and its expectancy effects.

Aristi Tsokani et al. (2023) explored perceptions of therapeutic green exercise among patients with chronic conditions and health professionals. Both groups were generally positive about the value of green exercise but identified obstacles like safety concerns, lack of infrastructure/accessibility, unfavourable weather, and subjective factors like patients' illnesses and lack of motivation. The study found that green exercise could offer benefits such as improved mental health, mood enhancement, nature connectedness, socialisation, and being more sustainable than indoor exercise. However, to promote physical activity for chronic conditions through green exercise, psychological barriers, accessible environments, and motivation need to be addressed.

The narrative review analysed the impacts of exercising in outdoor natural environments compared to indoor settings on various physiological and psychological outcomes. The review suggests that outdoor exercise, also known as "green exercise," may provide several cardiovascular benefits, such as higher heart rates and greater blood pressure reduction compared to indoor exercise. Outdoor athletes and those participating in outdoor sports also tended to have higher vitamin D levels, likely due to greater sunlight exposure. In terms of psychological effects, multiple studies found that exercising in nature improved mood, and reduced stress and depression symptoms more than indoor exercise, though some research did not find significant differences between settings. The effects on anxiety reduction were mixed. Some studies indicated that outdoor exercise may provide cognitive benefits like enhanced attention and working memory over indoor exercise, while other research favoured indoor exercise for cognitive improvement in older adults due to lower pollution. Viewing nature scenes/videos and exercising in actual outdoor natural environments was associated with psychological gains like increased emotional well-being compared to indoor/urban settings without nature exposure. Some studies also linked green exercise to greater feelings of social connectedness, belonging, and community. Overall, while findings were mixed, the review highlights potential physiological and psychological advantages of exercising in nature versus indoor environments, though more research is still needed to fully understand these benefits.

Practical implications

Practical implications include promoting outdoor exercise opportunities by creating and maintaining accessible green spaces, parks, and trails. Healthcare providers can incorporate outdoor exercise into treatment plans and wellness programs to enhance mood, reduce stress and anxiety, and improve adherence. Public education campaigns can raise awareness about these benefits and encourage engagement with nature. Efforts should address barriers like safety, infrastructure, and weather challenges. Monitoring and supplementing vitamin D levels can benefit indoor athletes. Outdoor exercise can complement mental health treatments like depression and anxiety. Virtual reality nature simulations combined with indoor exercise offer psychological benefits. Group outdoor activities foster social connections, enhancing overall well-being. Implementing these strategies can leverage nature's advantages for holistic well-being.

Limitations

This narrative review has potential limitations. The available literature on the topic may have been limited, impacting comprehensiveness. Publication bias could have skewed study representation. Time constraints inherent to research may have affected thoroughness. Access to resources like academic databases and journals may have posed limitations. Expertise level and language limitations could have influenced literature selection and interpretation.

Conclusion

In conclusion, this comprehensive research has explored the nuanced relationship between outdoor and indoor exercise and its impact on human health and well-being. The findings highlight the potential advantages of engaging in physical activity amidst natural settings while acknowledging the existing literature's complexities and inconsistencies.

Regarding cardiovascular health, several studies suggest that outdoor exercise, often called "green exercise," may elicit higher heart rates and greater physiological demand than indoor exercise. However, the evidence remains mixed, with some research indicating minimal differences in heart rate or perceived exertion between outdoor and indoor settings. Nonetheless, the potential benefits of outdoor exercise in lowering blood pressure and improving overall cardiovascular fitness should be considered.

The research also delved into the role of outdoor exercise in facilitating vitamin D production through sunlight exposure. While indoor exercise may not provide the same opportunities for vitamin D synthesis, the findings suggest that outdoor physical activity can effectively increase vitamin D levels, potentially contributing to enhanced mental health and mood regulation.

The impact of exercise environments on mood and stress reduction emerged as a prominent theme. Several studies reported positive effects of outdoor exercise on reducing perceived stress, enhancing mood states, and alleviating symptoms of depression and anxiety. However, some inconsistencies were observed, with a few studies failing to find significant differences between indoor and outdoor settings regarding mood and stress outcomes.

Cognitive performance and attention restoration were also explored, with the Attention Restoration Theory proposing that natural environments can enhance mental abilities and promote a state of "soft fascination." While some research supported the cognitive benefits of outdoor exercise, particularly in improving attention and working memory, other studies yielded conflicting results, suggesting that indoor exercise may be more advantageous in certain contexts or for specific cognitive domains.

The review also delved into nature connectedness, which refers to an individual's sense of belonging and affiliation with the natural world. Several studies highlighted the positive associations between engaging in outdoor activities, especially in green spaces, and experiencing enhanced mood states, reduced stress, and a more profound sense of relaxation and connection with nature.

Furthermore, the research explored the potential impact of virtual reality and simulated nature experiences on psychological and physiological outcomes. While some studies suggested that virtual reality could partially replicate the benefits of outdoor exercise, others emphasised the importance of direct exposure to natural environments for optimal well-being.

Acknowledging the limitations and complexities within this field of research is essential. Individual preferences, environmental conditions, and methodological variations across studies can influence the outcomes. Additionally, the generalisability of findings may be limited by sample characteristics and the specific types of outdoor and indoor settings investigated.

Further research is needed to disentangle the specific mechanisms underlying outdoor exercise's potential benefits and explore the optimal conditions for maximising these benefits across diverse populations and environments. Interdisciplinary collaborations and innovative research methodologies could contribute to a more comprehensive understanding of the intricate relationships between physical activity, natural environments, and human well-being.

Overall, this research narrative review underscores the importance of considering the exercise setting and its potential implications for cardiovascular health, vitamin D production, mood and stress regulation, cognitive performance, and nature connectedness. While the findings are inconclusive, they provide valuable insights and highlight the need for ongoing exploration of this multifaceted topic.

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