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A Scoping Review of the Health Benefits of Nature-Based Physical Activity

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Abstract

The health benefits of physical activity and spending time in nature are well established. However, youths and adults in the United States are not participating in sufficient levels of physical activity and are not spending much time outdoors. Recently, the need for equitable access to nature for all populations has been receiving more public health attention, though a specific focus on nature-based physical activity has been limited. The purpose of this scoping review is to operationalize the health benefits of nature-based physical activity in order to provide guidance for collaborations to program administrators, advocates, and researchers. Peer-reviewed literature is found in PubMed, Medline, Web of Science, and Google Scholar as well as in published reviews of the literature. The literature is divided into three categories of: 1) amount and location of nature-based components and physical activity; 2) added health benefits of exposure to nature-based components and physical activity; and 3) nature-based components and physical activity effect on non-white, marginalized, and vulnerable populations. This review supports and encourages multiple strategies to increase nature-based physical activity as this provides even greater benefit to health and wellness than exposure to nature or physical activity alone. Although many of the physical and mental health benefits of nature and physical activity are well established, additional research is needed to better understand the relationship between exposure to nature and nature-based physical activity, which will require greater investment and support from funding agencies.

Keywords: green exercise, mental health, nature-based components, nature-based initiatives, nature-based physical activity, outdoor physical activity

Introduction

The health benefits of physical activity (PA) are well established and include reduced risk of heart disease, stroke, hypertension, type II diabetes, certain types of cancer, and decreased symptoms of depression (Piercy et al., 2018). However, research also indicates that youths and adults are not engaging in sufficient PA to achieve these benefits. Recent estimates suggest that only 24-26% of children and adolescents are meeting the recommended aerobic guidelines of at least 60 minutes of moderate-to-vigorous PA (MVPA) per day (Katzmarzyk et al., 2018) while only 53.3% of adults are meeting recommended aerobic guidelines of at least 150 minutes of MVPA per week (Schiller et al., 2018). Given the health benefits and low participation rates, encouraging PA has been a focus of public health efforts including promoting structured exercise, active transportation (e.g., walking or biking for transport), and leisure-time PA.

A large and increasing body of literature points to the salutogenic effects of spending time in nature regardless of whether that time includes passive (e.g., viewing landscapes) or physically active behaviors (e.g., walking or hiking) (Bratman et al., 2019; Frumkin et al., 2017; Hartig et al., 2014; Kondo et al., 2018; McDonald et al., 2018; Twohig-Bennett & Jones, 2018). However, along with reduced PA levels, a decline has also occurred in the amount of time people spend outdoors engaging with nature. One cross-sectional study of over 2,000 children showed that between the years of 1981-82 and 2002-03 the amount of time children spent in unstructured outdoor activities declined from 100 minutes per week to 50 minutes per week (Hofferth & Sandberg, 2001; Juster et al., 2004). Similarly, the Canadian Human Activity Pattern Survey (CHAPS) reports that in the 15 years between the first survey (CHAPS 1, early to mid-1990's) and second (CHAPS 2, 2010-11) the amount of time youths spent outdoors decreased by 24-35 minutes per day, depending on age group (Matz et al., 2014). With respect to adults, the National Human Activity Pattern Survey estimated that during the period of 1992-94, adults in the United States spent about 109 minutes a day outdoors (Klepeis et al., 2001). Few studies report on historical trends in time outside or how time outside is spent by adults, but changes in video screen use and sedentary time suggest that the amount of time adults spend inside is increasing (Beyer et al., 2018; Du et al., 2019; Livingston, 2019). This impression is supported by a national survey of approximately 5,500 adults in the United States who reported that during 2015-16, half spent fewer than 5 hours per week, or less than 10% of each day, outdoors in nature, excluding organized sports in a typical week (Kellert & Case, 2018). It is important to note that rates of participation in outdoor recreation have increased markedly during the COVID-19 pandemic. According to the Physical Activity Council's annual participation survey, 2020 saw the highest rate of participation in outdoor recreation with 53% of Americans ages 6 and older recreating outdoors at least once (Outdoor Foundation, 2021). However, there is reason to believe that this increased participation could be temporary as only 20% reported participating in outdoor activities more than twice a week, continuing an existing downward trend prior to the pandemic, and a quarter of new participants in outdoor recreation indicated no desire to continue to participate in outdoor activities (Outdoor Foundation, 2021).

Nature health benefits

The foundational hypotheses for how engaging with nature improves health and well-being are derived from multiple fields of research, but with environmental psychology being the most common (Spencer & Gee, 2009). These hypotheses include the Attention Restoration Theory (Kaplan & Kaplan, 1989), the Stress Reduction Theory (Ulrich et al., 1991), and the Biophilia Hypothesis (Kellert & Wilson, 1995). More recently, additional hypotheses propose that cultural learning and place attachment contribute to the salutogenic effects of nature (Beery et al., 2015; Joye & De Block, 2011; Knez et al., 2018; Sampson, 2012). In brief, these hypotheses posit that engaging with nature improves mental and physical health via psychobiological pathways associated with changes in neuroendocrine, immune, and autonomic nervous system functions. In addition to these psychobiological pathways, evidence for more direct physiological pathways is increasing. For example, inhaling specific plant compounds (phytoncides) is associated with improved immune function (Kuo, 2015; Oh et al., 2017; Tsao et al., 2018). The presence of vegetation may also improve well-being by reducing exposure to air pollution or reducing urban heating (Dadvand et al., 2015; Donovan et al., 2013; Livesley et al., 2016; Yang et al., 2019). Exposure to nature also may influence the body's microbiome leading to changes in health status (Lowry et al., 2016; Prescott & Logan, 2016). Finally, given the recent effects of the COVID-19 pandemic, research evaluating the effects of the natural and built environment on PA and the impacts of disease transmission are increasingly relevant (Pinter-Wollman et al., 2018). Thus, this rich body of evidence provides the backdrop for exploring synergies between PA, the location where PA occurs, and the role of nature in public health.

Nature-based components

When evaluating spaces in communities, the language used in research and planning has often included different, and sometimes conflicting, terms around natural places, especially in different geographic areas (Layton, 2018). Table 1 provides definitions for key terms related to natural places to aid practitioners and researchers in working in this area. Recent research and professional practice in the United States has shifted to the use of the broad term "components" to describe the variety of places, lands, and facilities that are afforded to an individual (Layton, 2018). Components are defined as those things that individuals can visit and use in a community. These can include active spaces, such as ballfields, courts, picnic facilities, playgrounds, and trails. Modifiers can be safety, comfort and convenience amenities that support or enhance the overall experience of visiting the spaces, including such things as the availability of restrooms, drinking water,

shade, seating and overall comfort, convenience, scenic quality, accessibility features for populations with disabilities, and lighting (Layton, 2018). Additionally, the effect of racial discrimination and racial profiling has been identified as a key element to the safety and use of these spaces by non-white, marginalized populations (Lee & Scott, 2016).

Nature-based components are often called parks, green spaces, natural areas, conservation areas, forests, water-access, greenways, and a variety of other terms. Typically, these spaces have been defined as areas with predominant vegetative and/or geological features that reflect natural processes (e.g., trees, prairies, grasses) (Centers for Disease Control and Prevention, 2009; Frumkin et al., 2017; Hartig et al., 2014; Lachowycz & Jones, 2013; Taylor & Hochuli, 2017; World Health Organization, 2016). However, while much emphasis is placed on vegetation and greenness, this definition and the concept of restorative nature suggest that other types of natural environments such as water and desert environments may also provide benefits (De Vries, 2019; Kaplan & Kaplan, 1989; Kelly, 2018).

For simplicity, and because the body of literature reviewed for this paper emphasizes areas with trees and vegetation, in this commentary we will use the term components (typically meaning nature-based). The term green exercise has been applied to mean activity that is undertaken in locations that meet the definition of nature-based components or green space given above (Fraser et al., 2019; Olafsdottir et al., 2017; Pretty et al., 2003). We refer to nature-based PA rather than green exercise.

Table 1. Glossary of Key Terms

Term	Definition	Reference(s)
Blue Space	All visible surface water in a space; including oceans, lakes, rivers, streams, ponds, and other such waterscapes.	(Völker & Kistemann, 2011)
Brown Space	Areas where the space is dominated by soil type, rocks, and green is less prominent such as arid regions including desert landscapes.	(Nazif-Munoz et al., 2020)
Gray Space	Areas dominated by concrete, buildings, and other impervious surfaces typically characteristic of human-constructed environments.	(Nazif-Munoz et al., 2020)
Green Exercise	Physical activity undertaken in both urban and nonurban natural environments.	(Pretty et al., 2005)
Green Space	Areas dominated by natural and/or planted vegetation such as grass, plants, or trees.	(Klompmaker et al., 2018; Taylor & Hochuli, 2017)
Natural Environments	Landscapes dominated by blue space, green space, and/or brown space that contain flora and fauna that are minimally influenced by humans.	(Johnson et al., 1997; McIsaac & Brün, 1999)
Nature-based Components	Often called parks, green spaces, natural areas, conservation areas, forests, water-access, greenways, and a variety of other terms. Typically, these spaces have been defined as areas with predominant vegetative and/or geological features that reflect natural processes (e.g., trees, prairies, grasses).	(Frumkin et al., 2017; Lachowycz & Jones, 2013; Layton, 2018; Taylor & Hochuli, 2017; World Health Organization, 2016)
Nature-based Interventions	Programs, activities or strategies that aim to engage people in nature–based experiences with the specific goal of achieving improved health and well-being	(Shanahan et al., 2019)
Nature-based Therapeutic Interventions	Use of a natural area, specifically designed or chosen, for a therapeutic intervention.	(Stigsdotter et al., 2011)

Role of public health

The public health community is often torn between the desire to act and the desire for more evidence. Nowhere is this more apparent than with the rising interest in the role of nature-based components and PA as a means to improve public health. For example, in 2013 the American Public Health Association (APHA), the largest organization of public health professionals in the United States, promoted a policy statement (APHA PS20137) highlighting the relationship between time spent outdoors and PA and recommended 11 action steps to increase access to nature to improve public health (Chawla & Litt, 2013). The existence of this policy statement is a direct and profound declaration that it is in the interest of public health for

people to spend time in nature, regardless of whether that time is spent in PA or not.

Along these lines, in an article in Environmental Health Perspectives, Frumkin and colleagues (2017) describe the gaps in our knowledge about how exposure to nature improves health and propose a research agenda to address these key gaps in knowledge including the following: 1) the dosage of nature needed for significant health benefit, 2) the biomarkers of exposure to nature, 3) clarity on whether nature-based PA provides greater benefits than the equivalent PA in a non-nature based setting, and 4) the best strategies and approaches to promote exposure to nature within populations; including understanding what components of nature are salutogenic. Additionally, two more recent review articles state that the number of papers providing evidence for the beneficial effects of nature to specific health conditions is too low and the diversity of measures used too wide to make generalizable statements (Kondo et al., 2018; Twohig-Bennett & Jones, 2018).

The primary goal of this scoping review is to provide a foundation for those seeking to understand the breadth of information on the positive associations between exposure to nature-based components, PA, and health outcomes. We also provide guidance to program administrators, advocates, and researchers that will facilitate collaborations, promote evaluation and research programs, and inform interventions in the interest of identifying existing evidence that supports actionable programs and environment improvements.

Methods

The eleven broad categories of evidence on the connections between nature and health presented in the 2013 APHA policy statement served as the starting point for the literature review (Chawla & Litt, 2013). The current literature review focused on the connection between nature-based PA and specific positive health outcomes. Research literature focusing on nature-based PA in each of these eleven broad categories was searched in PubMed, Medline, Web of Science, and Google Scholar. In addition, original research was found in previously published reviews of the literature. The authors, representing a diverse range of academic and professional disciplines (biological anthropology, public health, kinesiology, and parks and recreation planners and practitioners) brought together through the CDC-organized Physical Activity Policy Research and Evaluation Network (PAPREN), met monthly to discuss the literature found. The literature was divided into three categories of: 1) Amount and location of nature-based components and PA; 2) Added health benefits of exposure to nature-based components and PA; and 3) Nature-based components and PA effect on non-white, marginalized, and vulnerable populations. Within each of these categories, subcategories were established to help summarize the breadth of evidence in meaningful ways for a variety of stakeholders. When exploring the literature for such evidence, descriptions of nature exposure included time spent outdoors or in a variety of environments commonly labeled as natural, green, blue, or brown environments.

It should be noted that this is not meant to be a systematic or comprehensive review of the literature. Rather, our goal was to provide a foundation for those seeking to understand the breadth of information on the positive associations between exposure to nature-based components and PA and health outcomes.

Results

To facilitate reading clarity, citations have been consolidated into tables associated with each section. Citations have been included in the text only when they are not directly associated with material contained in a table.

Amount and location of nature-based components and PA

Research has examined the relationship between the amount, proximity, and quality of neighborhood components on PA-related behavior across the lifespan. Amount of the components refers to the total number of available components, often described through amount of acreage or objective vegetative analyses that is within a "reasonable" distance (to walk, bike, or drive to) from a person's home. Location or proximity refers to the distance of the nearest component. Quality refers to the modifiers - features, amenities, and facilities of nearby components, such as maintained equipment, lighting, water fountains, bathrooms, parking, and trees for shade, biodiversity, and aesthetics. The literature reviewed below on the amount and location of nature-based components and PA is summarized in Table 2.

Children and Adolescents

Among children (<10 years of age) and adolescents (10-18 years of age), the amount of green space in the neighborhood is positively associated with increased MVPA. Among children and adolescent girls, closer proximity to green space is associated with increased MVPA. Several studies have found that in addition to adolescents having access to green space, spaces with higher quality facilities are associated with more MVPA, less sedentary behavior, and greater use of the green space.

Adults

Among adults (18-65 years of age), having more access to components is associated with increased MVPA and increased walking. Research shows that closer proximity to components is associated with increased MVPA, increased use, and increased walking. Increased MVPA and increased walking is also associated with the availability of both components and with quality modifying features (i.e., safe, aesthetically pleasing, has trees). Furthermore, one study found that perceived quality was a better predictor of visit frequency than objective measures of quantity of components (Flowers et al., 2016). Lastly, components with higher biodiversity as well as high quality modifiers

provided greater levels of psychological restoration than components with lower biodiversity.

Older Adults

Among older adults (>65 years of age) specifically, the amount of neighborhood components is related to higher levels of MVPA and increased sports-related activity. In addition, modifying features and amenities of components, as mentioned previously, were related to increased leisure-time PA while quality of components has been related to less decline in walking among older adults.

Table 2. Amount and Location of Nature-Based Components and Physical Activity

	Direction of Change	Selected Scientific Articles
Children and Adolescents		
Greater amount of nearby green space		
MVPA	↑	(Roemmich et al., 2006)[3]; (Janssen and Rosu 2015)[3] Boys, but not in girls (Sanders et al., 2015)[2]
Quality facilities		
MVPA	↑	Adolescents (Babey et al., 2008)[3]; (Cohen et al., 2006)[3]; (Epstein et al., 2008)[1]
Sedentary behavior	↓	Adolescents (Babey et al., 2008)[3]
Use of green space	↑	Adolescents (Edwards et al., 2015)[3]
Closer proximity to green space		
MVPA	↑	Children (Roemmich et al., 2006)[3] Adolescent girls (Cohen et al., 2006)[3]; (Rodriguez et al., 2012)[3]
Adults		
Greater amount of nearby green space		
MVPA	↑	(Astell-Burt, Feng, et al., 2014b)[3]; (Kaczynski et al., 2009)[3]; (Sallis et al., 2016)[3]
Walking	↑	(Astell-Burt, Feng, et al., 2014b)[3]; (Sugiyama et al., 2013)[2]
Closer proximity to green space		
MVPA	↑	(Coombes et al., 2010)[3]; (Ribeiro et al., 2013)[3]
Use of green space	↑	(Coombes et al., 2010)[3]
Walking	↑	(Giles-Corti et al., 2005)[3]; (Giles-Corti et al., 2013)[3]; (Gomez et al., 2010)[3]; (Sugiyama et al., 2010)[3]; (Sugiyama et al., 2013)[3]
Quality features and facilities		
MVPA	↑	(Kaczynski & Henderson, 2008); (Schipperijn et al., 2013)
Walking	↑	(Giles-Corti et al., 2005)[3]; (Gomez et al., 2010)[3]; (Koohsari et al., 2013); (Li et al., 2005)[3]; (Sugiyama et al., 2010)[3]
Visit frequency	↑	(Flowers et al., 2016)
Biodiversity		
Restorative response	↑	(Wood et al., 2018)[3]
Older Adults		
Greater amount of nearby green space		
MVPA	↑	(Gong et al., 2014)[2]
Sports-related activity	↑	(Hanibuchi et al., 2011)[1]
Quality features and facilities		
LTPA	↑	(Cerin et al., 2013)[3]
Decline in walking	↓	(Li et al., 2005)[3]

[1] Experimental study design
[2] Cohort study design
[3] Cross-sectional study design
↑ Increased
↓ Decreased

Added health benefits of exposure to nature-based components and PA

Beyond the benefits of PA, numerous benefits to physiological, mental, cognitive, and social health have been associated with both exposure to nature and nature-based PA. These are summarized in Table 3.

Physiological

A large number of anthropometric, biochemical, and neural outcomes have been used to assess the impact of engaging with nature on physiology and health. Nature and nature-based PA is associated with decreased heart rate, blood pressure, cholesterol, body mass index (BMI), and improved heart rate variability. Biochemical responses include positive impacts on enzymes such as alpha-amylase which aids glucose absorption; hormones such as cortisol (linked with stress and metabolic regulation) and dehydroepiandrosterone sulfate (linked with sex drive, osteoporosis and dementia); the immune system (e.g., interleukin-6 (IL-6), natural killer cells); and neurotransmitters such as noradrenaline, which mobilizes the brain and body for action, and dopamine, which plays a role in the motivational element of reward-motivated behavior. Greater parasympathetic and lower sympathetic nerve activity and improved sleep and circadian rhythms resulting from time spent outdoors has been found to further support nature's restful and restorative effects. As might be expected given the many positive impacts on physiological parameters, exposure to nature is associated with reduced incidence of stroke, hypertension, dyslipidemia, asthma, and coronary heart disease as well as risk of obesity, diabetes, preterm birth, small size for gestational age, cardiovascular mortality, and all-cause mortality. As noted in multiple meta-analyses, the diversity of measures and outcomes makes it difficult to arrive at generalizable trends or tailored recommendations for specific conditions. Therefore, more rigorous and coordinated research efforts are needed to better establish the physiological benefits of nature and nature-based PA (Bowler et al., 2010; Lachowycz & Jones, 2011; Thompson Coon et al., 2011; Twohig-Bennett & Jones, 2018).

Psychological/Emotional

Exposure to nature-based components and PA has long been associated with improved mental and emotional well-being, including increases in positive engagement, revitalization, relaxation, self-esteem, body image, energy, affective response, self-reported health and health-related quality of life. Likewise, exposure to nature is associated with reductions in negative symptoms and outcomes such as stress, anxiety, depression, and fatigue (World Health Organization, 2016). Exposure to nature has been shown to be an effective treatment for anxiety by providing a spectrum of sensory stimulations that focus attention and allow emotional processing to be external instead of internal (Detweiler et al., 2018).

Cognitive Function and Experience

Multiple mental abilities such as attention, learning, thinking, reasoning, remembering, problem solving, and decision-making are associated with exposure to nature-based components and PA. Experimental studies have shown that spending time in nature improves memory function, direct attention, increased neural activity associated with deep meditative states and daydreaming, improved child development, greater intelligence and academic performance, and lower levels of arousal and frustration. Further, nature exposure can influence how we make decisions about PA. For example, those who spend more time outdoors and interact more with nature report lower perceived effort for exercise and have greater frequency and duration of MVPA. Some studies also show that outdoor environments can influence preferred activities and types of play as well as engage less fit populations.

Social Relationships

Our social relationships play a major role in our overall health. Cross-sectional studies indicate that spending time in nature fosters social capital and social support that a person receives from others. This may be because time spent in nature provides opportunities and activities for socialization and formation of social networks. Nature exposure is also associated with greater social cohesion, a key aspect of the Healthy People 2020 Social and Community context domain, referring to the "strength of relationships and the sense of solidarity among community members" (US Department of Health and Human Services, 2010). This area of literature also points to the role nature and nature-based PA can have on social mobility and factors that may impact income/wealth accumulation such as health care spending.

Table 3. Added Health Benefits of Exposure to Nature-Based Components and Physical Activity

	Direction of Change	Selected Scientific Articles
Physiological (cardiovascular and metabolic parameters)		
Blood pressure	↓	(Park et al., 2010)[1]; (Twohig-Bennett & Jones, 2018)[2]; (Li et al., 2011)[1]; (Yang, Markevych, Bloom, et al., 2019)[4]
Diastolic blood pressure	↓	(Twohig-Bennett & Jones, 2018)[2]
Heart rate	↓	(Park et al., 2010)[1]; (Twohig-Bennett & Jones, 2018)[2]
Heart rate variability	↑	(Blum et al., 2019)[1]; (de Brito et al., 2020)[1]
Low frequency	↓	(Twohig-Bennett & Jones, 2018)[2]; (Park et al., 2017)[3]

High frequency	↑	(Twohig-Bennett & Jones, 2018)[2]
Nighttime	↑	(Gladwell et al., 2016)[1]
Body mass index (BMI)	↓	(Veitch et al., 2016)[4]; (Tilt et al., 2007)[4]; (Astell-Burt, Feng, et al., 2014a)[4]; (Li & Ghosh, 2018)[4]; (O'Callaghan-Gordo et al., 2020)[4]
Sleep/circadian rhythms		
Align internal rhythms with natural sunrise and sunset.	↑	(Wright et al., 2013)[1]
Sleep duration	↑	(Shin et al., 2020)[2]; (Johnson et al., 2018)[4]; (Astell-Burt & Feng, 2020a)[4]; (Wright et al., 2013)[1]
Sleep quality	↑	(Shin et al., 2020)[2]; (Pasanen et al., 2014)[4] (Xie et al., 2020)[4]
HDL cholesterol	↓	(Twohig-Bennett & Jones, 2018)[2]; (Fan et al., 2020)[4]
Markers of oxidative stress	↓	(Mao, Lan, et al., 2012)[1]; (Mao, Cao, et al., 2012)[1]
Alpha-amylase	↓	(Egorov et al., 2017)[4]; (Hunter et al., 2019)[3]
Cortisol	↓	(Park et al., 2010)[1]; (Egorov et al., 2017)[4]; (Hunter et al., 2019)[3]; (Honold et al., 2016)[4]; (Gidlow et al., 2016)[3]; (Twohig-Bennett & Jones, 2018)[2]
Adiponectin	↑	(Li et al., 2011)[1]; (Li et al., 2016)[1]
Dehydroepiandrosterone sulfate	↑	(Li et al., 2011)[1]
Pro-inflammatory cytokines (e.g., IL-6; TNF-α)	↓	(Mao, Lan, et al., 2012)[1]; (Mao, Cao, et al., 2012)[1]; (Oh et al., 2017)[2]
Anti-inflammatory cytokines (e.g., IL-8)	↑	(Egorov et al., 2017)[4]
Natural Killer Cells	↑	(Li et al., 2007)[1]; (Li et al., 2009)[1]; (Tsao et al., 2018)[1]
Allostatic Load	↓	(Egorov et al., 2017)[4]; (Ribeiro et al., 2019) [4]
Parasympathetic nerve activity		
Heart rate variability	↑	(Farrow & Washburn, 2019)[2]; (Park et al., 2010)[1]; (Park et al., 2017)[1]; (Lee et al., 2014)[3]; (Song et al., 2019) [1]
Sympathetic nerve activity		
Heart rate variability	↓	(Farrow & Washburn, 2019)[2]; (Park et al., 2010)[1]; (Park et al., 2017)[1]; (Lee et al., 2014)[3]; (Song et al., 2019)[1]
Urine adrenaline/noradrenaline/ dopamine	↓	(Li et al., 2008)[1]; (Li, 2010)[1]; (Li et al., 2011)[1]; (Li et al., 2016)[1]
Neurotransmitters		
Noradrenaline/adrenalin	↓	(Li et al., 2011)[1]; (Egorov et al., 2017)[4]
Dopamine	↓	(Li et al., 2011)[1]; (Li et al., 2016)[1]; (Egorov et al., 2017)[4]
Disease Prevalence/Risk		
Asthma	↓	(Twohig-Bennett & Jones, 2018)[2]; (Lovasi et al., 2008)[4]
Hypertension	↓	(Twohig-Bennett & Jones, 2018)[2]
Dyslipidemia	↓	(Twohig-Bennett & Jones, 2018)[2]
Obesity/metabolic syndrome	↓	(Nielsen & Hansen, 2007)[4]; (Lachowycz & Jones, 2011)[2]; (Ulmer et al., 2016)[4]; (Egorov et al., 2017)[4]; (Schalkwijk et al., 2018)[4]; Browning and Rigolon 2018[4]; (O'Callaghan-Gordo et al., 2020)[4]; (Huang et al., 2020)[4]; (Yang et al., 2020)[4]; (de Keijzer et al., 2019)[4]
Stroke	↓	(Twohig-Bennett & Jones, 2018)[2]; (Orioli et al., 2019)[4]
Coronary heart disease	↓	(Twohig-Bennett & Jones, 2018)[2]; (Wang et al., 2019)[4]
Diabetes type II/gestational	↓	(Twohig-Bennett & Jones, 2018)[2]; (Bodicoat et al., 2014)[4]; (Ulmer et al., 2016)[4]; (Egorov et al., 2017)[4]; (Yang, Markevych, Heinrich, et al., 2019)[4]; (Astell-Burt, Feng, et al., 2014b)[4]; (Qu et al., 2020)[4]
Pre-term birth/small size for gestational age	↓	(Twohig-Bennett & Jones, 2018)[2]
Cardiovascular mortality	↓	(Twohig-Bennett & Jones, 2018)[2]; (Yitshak-Sade et al., 2019)[4]
All-cause mortality	↓	(Villeneuve et al., 2012)[4]; (James et al., 2016)[4]; (Twohig-Bennett & Jones, 2018)[2]; (Rojas-Rueda et al., 2019)[2]; (Crouse et al., 2019)[4]

Psychological/Emotional Parameters		
Well-being	↑	(Korpela et al., 2017)[4]; (Pasanen et al., 2018)[4]; (Pasanen et al., 2014)[4]; (MacKerron & Mourato, 2013)[4]; (Marselle et al., 2013)[4]; (White et al., 2019)[4]; (Triguero-Mas et al., 2015)[4]; (Thompson Coon et al., 2011)[2]
Positive engagement		
Revitalization		
Tension		
Confusion		(Thompson Coon et al., 2011)[2]
Anger		(Thompson Coon et al., 2011)[2]
Risk of Poor Mental Health	↓	(Mitchell et al., 2013)3[4]
Emotional Experience		
Relaxation	↑	(Aspinall et al., 2015)[3]
Frustration	↓	
Self-esteem	↑	(Barton et al., 2012)[3]; (Barton & Pretty, 2010)[2]; (Swami et al., 2016)[4]
Body image/appreciation	↑	(Swami et al., 2019)[4]
Stress	↓	
In children	↓	(Razani et al., 2019)[1]
In adults	↓	(Kondo et al., 2018)[4]; (Marselle et al., 2013)[4]; (Nielsen & Hansen, 2007)[4]; (Largo-Wight et al., 2011)[4]; (Wooller et al., 2018)[1]; (Corazon et al., 2018)[4]; (Grahn & Stigsdotter, 2003)[4]
Stress related illnesses	↓	
Risk of Psychological Distress	↓	(Francis et al., 2012)[4]; (Astell-Burt & Feng, 2019)[4]
Anxiety	↓	(Niedermeier et al., 2017)[1]; (Bratman et al., 2015)[1]; (Mackay & Neill, 2010)[3]
Depression	↓	(Thompson Coon et al., 2011)[2]; (Egorov et al., 2017)[4]; (Irandoust & Taheri, 2017)[1]
Rumination	↓	(Bratman et al., 2015)[3]
Child resilience	↑	(Razani et al., 2019)[1]
Affective Response	↑	(Niedermeier et al., 2017)[1]
Affective valence	↑	(Bratman et al., 2015)[1]
Activation	↑	(Niedermeier et al., 2017)[1]
Elation	↑	(Niedermeier et al., 2017)[1]
Calmness	↑↓	(Niedermeier et al., 2017)[1]
Negative affect	↓	(Bowler et al., 2010)[2]; (Thompson Coon et al., 2011)[2] (Marselle et al., 2013)[4]; (Bratman et al., 2015)[1]
Mood	↑	(Barton et al., 2012)[3]; (Gidlow et al., 2016)[3]; (Barton & Pretty, 2010)[2]; (Wooller et al., 2018)[1]
Energy	↑↔	(Legrand et al., 2018)[1]; (Thompson Coon et al., 2011)[2]; (Kjellgren & Buhrkall, 2010)[1]
Vitality	↑	(Bowler et al., 2010)[2]; (Thompson Coon et al., 2011)[2]; (Kjellgren & Buhrkall, 2010)[1] (Ryan et al., 2010)[1,3]; (Niedermeier et al., 2017)[1]
Fatigue	↓	
Self-reported good health	↑	(Pasanen et al., 2014)[4]; (White et al., 2019)[4]; (Sugiyama & Ward Thompson, 2007)[4]; (Triguero-Mas et al., 2015)[4]; (Kyttä et al., 2012)[4]; (Twohig-Bennett & Jones, 2018)[2] (Stigsdotter et al., 2010)[4]; (Kim et al., 2016)[4] (Astell-Burt & Feng, 2019)[4]; (Stigsdotter et al., 2010)[4]
Health-related Quality of Life	↑	
Poor Health	↓	
Cognitive Function Cognition & Experience Parameters		
Memory	↑	(Gidlow et al., 2016)[3]; (Flouri et al., 2019)[4]; (Astell-Burt & Feng, 2020b)[4]
Direct Attention	↑	(Bowler et al., 2010)[2]; (Rogerson et al., 2016)[3]
Social Interaction Time	↑	(Rogerson et al., 2016)[3]; (Aram et al., 2019)[4]; (Rasidi et al., 2012)[4]
Restoration Experience	↑	(Gidlow et al., 2016)[3]; (Pasanen et al., 2018)[4]; (Bailey et al., 2018)[3]
Healthy Child Development	↑	(Gill, 2014)[2]
Intelligence/Academic Performance	↑	(Browning & Rigolon, 2019b)[2]; (Bijnens et al., 2020)[4]; (Li et al., 2019)[4]; (Kuo et al., 2018)[4]
Perception of Required Effort for Exercise	↑↓	(Gladwell et al., 2013)[2]
	↓	(Lahart et al., 2019)[2]

Nature Engagement	↑	(Han & Wang, 2018)[3]
Frequency of Exercise	↑	(Hug et al., 2009)[4]
Engagement in and Duration of Moderate-to-Vigorous Physical Activity	↑	(Beyer et al., 2018)[4]; (Wood et al., 2014)[3]; (Byrka & Ryczko, 2018)[4]; (Cleland et al., 2008)[4]
Play Styles (Children)	↑	(Gill, 2014)[2]; (Sandseter et al., 2020)[4]
Social Parameters		
Socialization Opportunities and Activities	↑	(Fan et al., 2011)[4]
Social Support	↑	(Fan et al., 2011)[4]
Social Capital	↑	(Holtan et al., 2015)[4]; (Maas et al., 2009)[4]
Social Cohesion	↑	(Ruijsbroek et al., 2017)[4]; (de Vries et al., 2013)[4]; (Sugiyama & Ward Thompson, 2007)[4]; (Liu et al., 2020)[4]
Social Mobility	↑	(Browning & Rigolon, 2019a)[4]
Health Care Spending	↓	(Becker et al., 2019)[4]

[1] Experimental study design
[2] Literature review or meta-analysis
[3] Quasi experimental study design
[4] Non-experimental/observational study design
↑ Increased
↓ Decreased
↑↓ Conflicting results
↔ No change

Nature-based components and physical activity effect on non-white, marginalized, and vulnerable populations

Typically, low-income and racial/ethnic minority individuals and communities experience disparities in access to facilities and resources compared to higher income and non-Hispanic white individuals and communities. This is also reflected in that opportunities for PA are often not equal across all segments of society. Similarly, there are disparities in public policies associated with parks and recreation management (Spangler & Caldwell, 2007). The literature reviewed is summarized in Table 4.

Environmental Justice

According to Bullard (2021), "environmental justice embraces the principle that all people and communities have a right to equal protection and equal enforcement of environmental laws and regulations…Reducing environmental, health, economic and racial disparities is a major priority of the Environmental Justice Movement." While the concept of environmental justice is broadly concerned with unwanted land use such as landfills, air and water pollution, commercial operations as well as tribal programs and policies, it has implications for components related to limiting nature exposure for low-income and minority groups in terms of urban design, access to and quality of outdoor recreation. Disparities in environmental justice are associated with disparities in outdoor PA opportunities and resources. For example, component quality has been found to vary by neighborhood race and income differences. These are likely related to historical and current disparities in policies, funding, and investment for various components in different neighborhoods and communities. One example is the continued effect of "redlining" or past discriminatory policies that restricted home ownership among racial minorities that resulted in various social and environmental issues still present today (Locke et al., 2021). These include urban neighborhoods with a high percentage of racial minorities having fewer nature-based components such as parks, green space, and trees for shade. Policies can help to address these disparities in public parks and recreation services. Calls have been made for public health and parks and recreation researchers and practitioners to collaborate on these topics.

Non-White, Marginalized, and Vulnerable Populations

A related issue has to do with Non-white marginalized and vulnerable populations' perceptions that natural spaces are controlled by and for dominant economic and racial groups (Finney, 2014). This may result in fear or less desire to use natural spaces as they may be seen as not welcoming or not for the desired uses of those groups. However, this concept may be associated with specific cultures and geographies (Hagerhall, 2018). Generally, marginalized and vulnerable groups have worse health outcomes and worse access to natural environments, yet natural environments may be important to addressing disparities by encouraging PA, improving mental outlook, and reducing psychological stress and thereby increasing life expectancy (Lachowycz & Jones, 2014). Studies of women in nature have found that fear of natural spaces may add to the under-representation of women in this area of research. In terms of populations with disabilities, there is limited research focusing on individuals with disabilities in nature with most of the research focusing on accessibility of components. Studies have examined the relationship between PA, inactivity, and health among indigenous

groups and have found results similar to those for other groups with inverse relationships between markers of negative health outcomes with levels of PA (Evans et al., 2018; Macniven et al., 2017; Pelletier et al., 2017). Additionally, these groups have been shown to have higher rates of obesity (Hedayat et al., 2018; Kumanyika, 2019). However, this study found no research which included exposure to nature as a variable of interest in these relationships.

Table 4. Nature-Based Components and Physical Activity Effect on Non-White, Marginalized, and Vulnerable Populations

	Trend Among Minorities and Low-Income Communities	Selected Scientific Articles
Access and Awareness		
Close Park Proximity	↑↓	(Rigolon, 2017)[4]; (Rigolon, 2016)[2]; (Taylor et al., 2007)[2]; (Rigolon & Németh, 2018)[4]; (Jennings & Gaither, 2015)[2]; (Wolch et al., 2014)[2]
Park acreage	↓	(Rigolon, 2017)[4]; (Rigolon, 2016)[2]; (Weiss et al., 2011)[4]; (Rigolon & Németh, 2018)[4]; (Cohen et al., 2016)[4]; (Astell-Burt, Feng, Mavoa, et al., 2014)[4]
Number of parks	↑↓	(Rigolon, 2016)[2]; (Weiss et al., 2011)[4]; (Vaughan et al., 2013)[4]; (Moore et al., 2008)[4]; (Abercrombie et al., 2008)[4]; (Gordon-Larsen et al., 2006)[4]
Low/no cost	↓	(Moore et al., 2008)[4]; (Dahmann et al., 2010)[4]
Number of facilities/programs within park	↑↓	(Kamel et al., 2014)[4]; (Cohen et al., 2013)[4]; (Moore et al., 2008)[4]; (Dahmann et al., 2010)[4]
Sense of belonging	↓	(Finney, 2014)[2]; (Byrne, 2012)[4]; (Das et al., 2017)[4]
Awareness of national parks	↓	(Xiao et al., 2018)[4]; (Johnson et al., 2007)[4]
Quality of Space		
Poor quality amenities	↑↓	(Taylor et al., 2007)[2]; (Rigolon, 2016)[2]; (Engelberg et al., 2016)[4]; (Jones et al., 2015)[4]; (Vaughan et al., 2013)[4]; (Cohen et al., 2013)[4]
Safety/maintenance	↓	(Moore et al., 2008)[4]; (Rigolon, 2017)[4]; (Rigolon, 2016)[2]; (Kamel et al., 2014); (Das et al., 2017)[4]
Safety from crime	↓	(Weiss et al., 2011)[4]; (Kamel et al., 2014); (Wolch et al., 2014)[2]
Parks perceived as less safe	↑	(Byrne, 2012)[4]; (Mitchell et al., 2018)[4]; (Boslaugh et al., 2004)[4]; (Tappe et al., 2013)[4]; (Cohen et al., 2013)[4]; (Foster & Giles-Corti, 2008)[2]
Funding		
For natural space/parks	↓	(Henderson & Fry, 2011)[4]

[1] Experimental study design
[2] Literature Review or meta-analysis
[3] Quasi experimental study design
[4] Non-experimental/observational study design
↑ Increased
↓ Decreased
↑↓ Conflicting results

Discussion

Research indicates that nature-based PA provides numerous physical and mental health and wellness benefits across the lifespan. These benefits stem from both the exposure to nature itself and engaging in PA and when combined have the potential for exponential return. However, access to nature components for PA is not universal and therefore presents an opportunity for public health to intervene.

Gaps in knowledge

This review focused primarily on positive associations between exposure to nature-based components and PA and health outcomes, in support of the research agenda put forth by Frumkin et al. (2017). We noted several limitations of the current state of literature including the lack of high-quality study designs. Most of the research was cross-sectional with few cohort or experimental study designs such as randomized clinical trials. Some limitations that contributed to the paucity of well-designed research is the lack of a consistent definition and measurement of nature exposure and standardized terminology, including the type (e.g., green, blue, brown), quality, and duration of exposure as well as the difficulty of designing a control condition. Further, many studies only explore acute health responses rather than long-term outcomes. As suggested by Thompson Coon et al. (2011, p. 1761), "Large, well designed, longer term trials in populations who might benefit most from the potential advantages of outdoor exercise are needed to fully elucidate the effects on mental and physical well-being." A few such studies are being undertaken. Examples from the US include a cluster randomized trial (South et al., 2018), two randomized controlled trials of park prescriptions (Müller-Riemenschneider et al., 2020; Razani et al., 2018), and two natural experiments that have recently received funding from the National Institutes of Health (Pearson et al., 2020; U.S. National Library of Medicine, 2020). Yet, given the potential of nature and nature-based PA for treatment and management of health and well-being, much more work is needed which will require greater research funding at the federal level. Another gap in knowledge exists in research focusing on access to high quality nature-based components among non-white, marginalized, and vulnerable populations. While much of the current research has focused on the perceptions of these populations related to access, there is a need for more research on why these perceptions exist in the first place in terms of history of segregation of shared public space and the impact on the current state of "who belongs" in these spaces.

Other limitations are associated with both the paucity and inconsistency of objective measures of health outcomes. Thanks to technological advances such as mobile EEG (Aspinall et al., 2015) and the development of field-friendly methods for collecting blood samples (e.g., dried blood spots; McDade et al., 2007) and saliva (Adam & Kumari, 2009), the use of biomarkers is increasing and available to researchers outside of traditional biomedical settings. However, the diversity of biomarkers available makes it difficult to compare outcomes across studies (Kondo et al., 2018; Twohig-Bennett & Jones, 2018). It is hoped that as the field advances there will be increased harmonization in the selection of biomarkers as their use expands. Finally, different stakeholders may desire information about different types of objective measures. For example, health insurance companies may value information about the number of visits to providers, but physicians may value data on the changes in a biomarker related to a specific disease. Thus, knowing the audience will be important as the field moves forward.

It is also important to note that while research provides support for the health benefits of exposure to nature-based components and PA, specific populations may not potentially benefit equally. This could be especially true for populations suffering from certain mental health illnesses, such as post-traumatic stress disorder (PTSD), stemming from traumatic events that occurred in outdoor environments. More research is needed to understand the effect of nature exposure on these populations and potentially how best to facilitate that exposure to create positive experiences.

Recommendations and action steps for increasing access to nature-based PA

The 2013 APHA policy statement explicitly states that increasing exposure to nature should be considered a public health issue regardless of any connections with PA and provides action steps that should be taken to increase access to nature for all populations (Chawla & Litt, 2013). The literature presented here provides support for increasing access and exposure to nature to increase nature-based PA to further increase health benefits over other forms of PA (indoor or active outdoor). However, as indicated by Frumkin et al., (2017), it is important to note that although the current evidence sufficiently supports action, it is clear that more large-scale biomedical research is needed. This will require increased support from major funding agencies such as the National Institutes of Health to fully examine the type and dose of nature exposure on clinical health outcomes in order to assess the potential of nature and nature-based PA as a prevention and/or treatment strategy.

Improving Access to Nature for All Populations

City and town governments, planners, parks and recreation agencies, and private organizations should all prioritize access to nature regardless of urbanicity, rurality, and socioeconomic level. Improving access to natural settings can provide increased opportunity for PA for populations at risk of inactivity. Several tools exist to assess access, maintenance, and to facilitate park use such as the Electronic Community Park Audit Tool, and others (eCPAT/ParkAdvisor; Bedimo-Rung et al., 2006; Besenyi et al., 2016; Besenyi et al., 2018; Gustat et al., 2020).

Currently, access to green space is inequitably distributed (Dai, 2011). A recent report suggests that parks that serve people of color are half the size and five times as crowded as parks that serve majority white populations and parks that serve low-income households are one quarter the size and four times as crowded as parks serving high-income households (Trust for Public Land, 2020). Data on the relationships between health outcomes, access to green space, and the presence of socioeconomic and racial/ethnic disparities, while at times conflicting, suggest that living near high quality green spaces improves health and well-

being (Browning & Rigolon, 2018). Structural and individual characteristics may influence greenspace use among low-income households (Cronin-de-Chavez et al., 2019). Park and green space use is influenced by culture and ethnicity (Egerer et al., 2019; Rishbeth et al., 2019; Seaman et al., 2010; Sefcik et al., 2019; Zenk et al., 2020). Among other things, concerns for safety, presence of trash, poor amenities, lack of knowledge of where to go, or inability to travel to a space may limit people's use of parks and green space. However, improving nature-based components in low-income areas also comes with inherent risk, such as the issue of green gentrification whereby these improved areas begin to attract wealthier residents that subsequently leads to displacement of low-income households (Anguelovski et al., 2019). Rigolon and Christensen (2019) have identified several strategies for various public sectors to reduce these negative impacts including engaging local community organizations and the people they serve to educate local government officials and policymakers about potential threats and challenges of creating new parks and green space to nearby neighborhoods. Adhering to the principles of community engaged programming and research presents another strategy to involve residents at the local level (Dick, 2017). While disparities in the presence of parks, vegetation, and high quality green spaces are associated with poorer health outcomes, more rigorous studies of how people want to use the spaces are needed to ensure that the spaces provided meet the needs of the people they are intended to serve while decreasing the potential negative impact associated with green gentrification (Mears & Brindley, 2019). One way to develop equitable advocacy is to include local trusted community champions representing under-resourced populations when completing community systems planning.

Education on Nature and Nature-Based PA

While the benefits of PA are fairly well known to the public, the added health benefits of time spent in nature and nature-based PA are not. Therefore, public health and health care professionals should educate and promote nature-based PA. Currently, there is a growing movement whereby health care providers prescribe nature-based PA to patients in a similar fashion to medication, however, these health care providers seldom receive training or insurance reimbursement to write these prescriptions or counsel patients on nature-based PA (James et al., 2019; Swinburn et al., 1997; Van den Berg, 2017). Therefore, incorporating nature-based PA and related evidence into professional curricula for public health and health care professionals and providing park prescription program training is needed to increase education and support (Besenyi et al., 2020). Additionally, health insurance companies should provide appropriate reimbursement to health care providers who take the time to counsel patients on nature-based PA.

Examples of successfully promoting nature-based PA exist such as "walk and talk therapy" where patient and therapist take a walk in nature while talking during a therapeutic session (van den Berg & Beute, 2021). To promote nature-based PA during the winter months throughout Canada, colorfully lighted public spaces, art structures, and neighborhoods as well as outdoor markets promote walking while public "warming huts" make various nature-based activities more comfortable (Dobrota & Armour, 2020). Another strategy that several local public health departments have adopted is to dedicate staff to promoting nature-based PA as was done in Mesa County, Colorado where a full-time permanent Trail Consultant position was created (Mesa County Public Health, 2021).

Increased Access to Community Nature-Based Components

Creating nature-based components in communities, such as gardens, pocket parks, parks, access to water, and trails, can increase opportunities for nature-based PA, especially in urban areas. This can be done in communities to positively change perceptions of neighborhood safety that can promote walking, biking, and other forms of PA. For all youths, nature provides settings that can promote PA through play by increasing non-competitive and unstructured forms of play. For these reasons, it is important that school grounds be considered for strategies to improve child health (Dyment & Bell, 2008; Herrington & Brussoni, 2015). These can include school gardens and natural landscaping in schoolyards for outdoor recess. Audit tools such as the Play Space Audit Tool exist to assist communities in assessing their play spaces (Gustat et al., 2020).Whenever possible, a research and evaluation component should be included with such interventions to provide much needed data on long-term impacts on PA and health outcomes.

Improving Safe Active Transportation

Active transportation refers to forms of PA that can be used to get from one point to another (e.g., parks and green space) such as walking and biking. Active transportation has been shown to be associated with higher overall levels of PA (Smith et al., 2017). Programs such as Safe Routes to School (Safe Routes Partnership, 2021b), Safe Routes to Play (GP RED, 2018), and Safe Routes to Parks (Safe Routes Partnership, 2021a) are examples of efforts to promote active transportation in communities. Nature-based strategies such as building and networking complete streets, trails, and greenways can be employed to connect access to nature-based components.

Conclusion

The physical and mental health benefits of nature and PA are well established, however more research is needed to fully understand the relationship between exposure to nature-based components and PA. This scoping review emphasizes that there is ample evidence to support that action steps be taken to increase access to nature-based PA to provide a greater health benefit through the combined effects of exposure to nature-based components for PA.

Author Contributions

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